Beyond Health. The Exploitation of Thermomineral Sources in Artisan Activities

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Introduction

In recent years, the study of thermomineral sources exploited during the Roman age has led to a large critical output mostly related to their use for curative activities.[1] At the Department of Cultural Heritage of Padua University thanks to a complex database for the census of all the archaeological, literary and epigraphic records attested in the Italian area[2] and in the northern Roman provinces of *Germania* and *Gallia*,[3] the research team has proposed an in-depth analysis of the different contexts attested from 2nd century BC to 4th century AD. Because of the wealth of evidence, we have defined some methodological starting points,[4] for recognizing the types of settlements,[5] the healing structures built close to the sources,[6] the worship places and the offerings dedicated to the deities,[7] the social and the legal aspects, as well as the geological, chemical and curative elements.[8]

But besides the clearer data of public buildings for healing purposes and of luxurious structures such as the Roman *villae*, useful to cater for all the needs of the pilgrims and ancient users, further archaeological contexts strictly linked to the thermomineral springs have been appearing and they cannot be classified as curative pools, worship places or villas, but probably rather as artisan buildings.

Indeed, there are few studies for the Roman period aimed at identifying places and structures/infrastructure built to use all the by-products extracted from the mineral springs themselves,[9] in other words the minerals, salts and concretions that normally accumulate where the waters exit. These hydrothermal deposits are a sub-category of the products derived from geothermal phenomena, for which a general classification has been proposed. Hydrothermal by-products include silica, borax and boric acid, iron oxides and sulphur, alongside sedimented carbonates such as travertine. The secondary uses of hydrothermal derivatives also include the exploitation of thermal heat for heating purposes and the driving force of the water itself, for example to power mills.

Starting from a general classification of the most common mineral salts attested at known Italian curative springs and their secondary uses, which can be compared with similar ones in other sites of the Roman Empire, this paper will therefore present some archaeological features discovered in Italy with specific markers of the mining of mineral concretions from thermomineral waters. Furthermore, an overview of both some ancient literary sources and some testimonies from the previous centuries will contribute to propose new elements for attempting to understand the multiple exploitation of the mineral sources in the Roman age.

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Distribution of Springs in Italy and Classification of the Principal Hydrothermal By-Products

As is known, to be described as mineral or thermomineral a water must be rich in dissolved salts.[10] The enrichment process starts with rainwater: after falling on the ground the water descends by percolation into the deep layers of the subsoil and comes into contact with mineral-rich rocks, which vary from place to place. Here it is mineralized and then rises back to the surface along specific underground paths. The water is classified as hypothermal (< 30°C) if it does not encounter sources of heat, whilst if it comes into contact with geothermal phenomena it may be described as homeo/hyperthermal (> 30°C).

The painstaking work to catalogue archaeological features in the vicinity of the thermomineral springs of ancient Italy, with further in-depth studies currently in the final stages on the larger and smaller islands, has made it possible to identify over 150 ancient contexts georeferenced in a web-GIS environment. As noted in the introduction, most of these are public bathing facilities of differing size and complexity, cult places, private villas and even, in some cases, probable *hospitia*; a less well represented, but no less interesting, group are smaller structures of uncertain function that may therefore, in some cases, be spaces for processing the hydrothermal by-products.

Cataloguing these settlements has also allowed us to propose a subdivision of the principal typologies of waters attested. Examining Table 1, we see that around a dozen mineral waters can be listed on the basis of their saline component: those rich in sulphur, sodium, calcium, magnesium and iron, alongside those containing traces of substances of plant or organic origin such as bituminous waters. The same table also contains a general outline of the main uses for the various types of water to treat various ailments of human and animals.

SALT TYPE	FIXED SOLIDS (mg/l)	THERAPEUTIC PURPOSES
bicarbonate	> 600	For digestion (contrasts acidity)
sulphate	> 200	As a laxative for hepatobiliary problems; also effective for dermatological, respiratory and articular problems
chlorine	> 200	For intestinal, biliary and liver problems; as a laxative
calcium	> 150	For calcium deficiency (pregnancy, menopause, osteoporosis and hypertension)
magnesium	> 50	For digestion
iron	> 1	For anaemia and iron deficiency
sodium	> 200	For sporting activities (to replenish mineral salts)
hypo-sodium	< 20	For arterial hypertension

Table 1. Principal salts present in thermomineral waters and their therapeutic purposes (as proposed by A. Bassani).

GEOTHERMAL BY-PRODUCTS	SECONDARY USES (AS BASIC INGREDIENTS OR ADDITIVES) FOR:
Various hydrothermal compounds and fumarolized vulcanites	Ordinary pottery and fine ceramics; concrete mortars and construction materials; fuller's earth and the treatment of textiles
Borates, oxides of iron and sulphur (sulphur dioxide)	Slips and glazes for fine ceramics; colorants; medicines (weak acids, pomades, unguents)
Sinter (hydrothermal silica)	Abrasives
Travertine	Construction blocks or cladding slabs for important buildings (columns, palaces, temples)
CaCo3 from hot waters saturated with CO2	Waterproofing of small channels in earth or bricks
Igneous rocks	Construction materials; millstones; road surfaces
Obsidian/natural volcanic glass	Stone tools; mirrors

Table 2. Classification of geothermal by-products for which some uses have been found (as proposed by R. Cataldi).

Referring those interested to the published studies on these issues mentioned above,[11] here I wish to focus instead on the minerals making up the hydrothermal by-products, either dissolved within the waters or present in solid form at the springs. Remembering that these hydrothermal derivatives represent a sub-category of geothermal products, summarily listed in Table 2, Table 3 shows that for a given product present in the vicinity of springs one or more uses in manufacturing, construction, agriculture or in the home are documented.

I will then present some archaeological contexts that can be analysed in the attempt to understand if, based on the indicators that they present, these can be interpreted in light of what we have said so far.

Archaeological Contexts near Sulphur Springs

As is known, the presence of sulphur salts in thermomineral waters (in which they were dissolved) and in the mineral concretions formed at these springs (where they took the form of yellow-ochre coloured crystals) was recognised already in the Greek world, which used the term *theion* for this precious material.[12] It can indeed be described as a precious substance both for its numerous curative uses and for its domestic and artisanal purposes, as well as its use in religious ceremonies: it is no surprise that in Greek the same word is used both for sulphur and for the divine.

Turning our attention to the identification of settlements in the vicinity of sulphur springs used for non-therapeutic purposes during the Roman period, an instance that

HYDROTHERMAL BY-PRODUCTS	SECONDARY USES (AS BASIC INGREDIENTS OR ADDITIVES) FOR:
Borax and boric acid (R. Nasini)	Slips and glazes; treatments in the textile industry
Sulphur (Pliny the Elder; modern authors)	Whitening and softening substances; flammable substances; purification of spaces; treatment of wool; maceration of linen and hemp
Iron oxides (modern authors)	Pottery
Calcium carbonate (Vitruvius, Pliny the Elder, Seneca)	Stone encrustations; canals in agricultural and rural areas
Sodium chloride/rock salt (Arrian; Herodotus; Synesius; Claudian; modern authors)	Dietary uses; religious uses (sal hammoniacus-Siwa); use for construction in arid areas
Bitumen (Pliny the Elder)	Oil for lamps; cladding of water conduits; coating of bronze or iron objects; cementification
Thermomineral muds (modern authors)	Potential uses in pottery
Thermal heat (Pliny El.; Cassiodorus; S. Mandruzzato)	Cultivation of some plants even during the cold season; distillation of alcohol; maceration of linen; extraction of silk from cocoons; hatching of eggs in incubators; facilitated cooking of legumes, pasta, fruit
Driving force (J. Dondi, A. Vallisneri; S. Mandruzzato)	Mills, spinning wheels

Table 3. Classification of hydrothermal by-products for which both ancient sources (Pliny the Elder, Vitruvius, Seneca etc.) and modern sources (J. Dondi, A. Vallisneri, R. Nasini etc.) indicate a non-therapeutic secondary use (with case-by-case variations depending on the individual springs).

merits detailed analysis is a private context in Lazio discovered at Acqua Zolfa, on a promontory that now forms part of the Tor Caldara Nature Reserve (Ardea, Lazio)[13].

Like most thermomineral archaeological contexts in Lazio, this site too has numerous mostly hot springs, with a prevalently sulphuric salt composition; around the springs are extensive banks of yellow sands and numerous quarries for the extraction of sulphur, attested at least from the modern period to the mid-19th century.

This type of extractive and perhaps also productive activity, as we shall see shortly, must have far more ancient origins, going back to the Roman period. In this same area, behind a small portion of a maritime villa built on terraces, of which a *nymphaeum* and a few other rooms are known (fig. 1, site L),[14] the soundings undertaken in the 1980s identified a series of quarries and tunnels for the extraction of sulphur, alongside basins for collecting the spring water, rich in its derivatives, and some rooms that seem to have been intended for the production of sulphur cakes. The map in Fig. 1 shows some sites (in particular A–G) with large deposits of particular ceramic objects: here there was an abundance of large jars with a hole on the shoulder, in addition to numerous

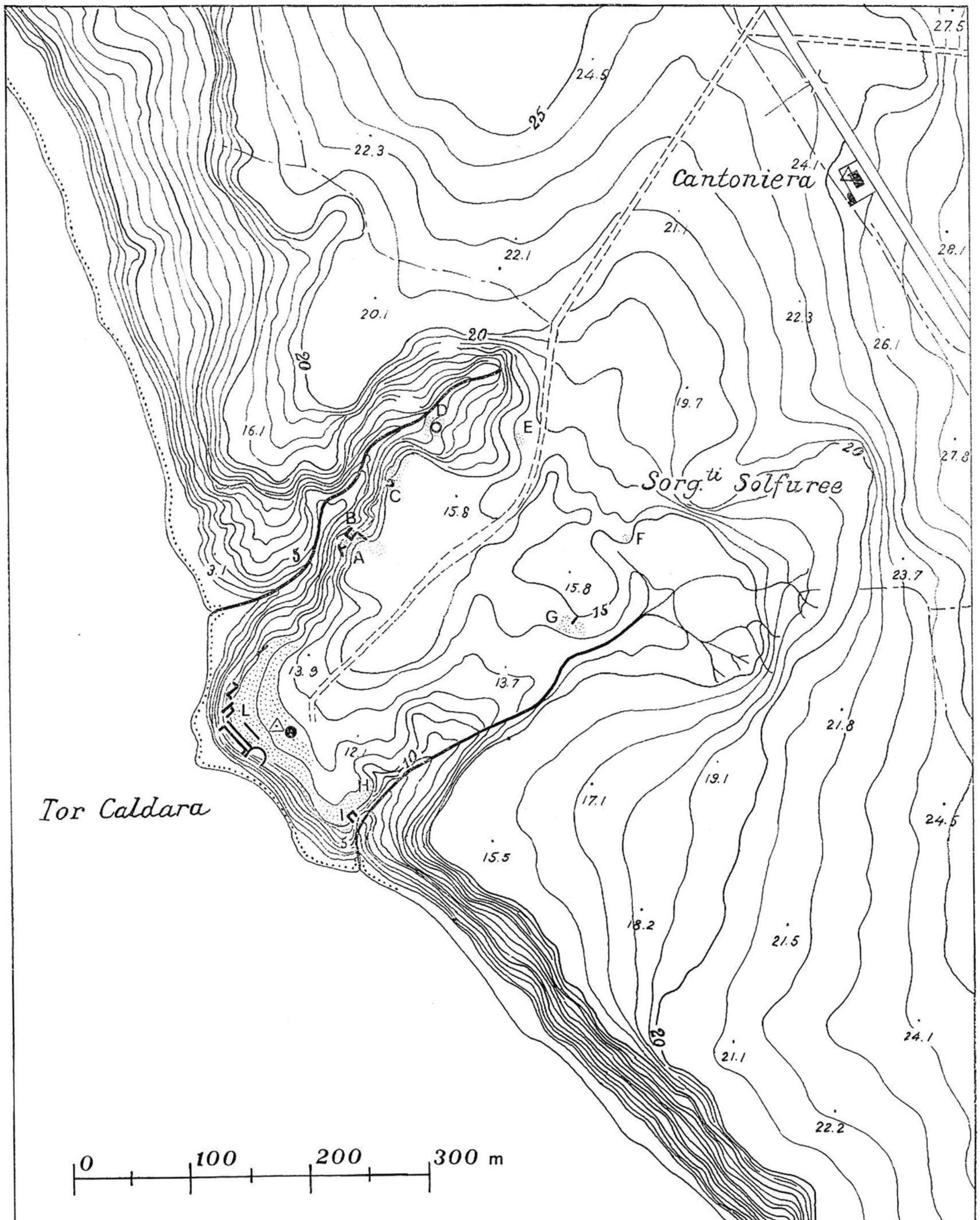

Fig. 1: Ardea, *Latium.* Topographical map of the Roman *villa* with its production places.

remains of tubes that must have been inserted into these (fig. 2). Thanks to a helpful comparison with the extraction processes used in the 16th century (fig. 3, 1–3),[15] and on the basis of more recent evidence,[16] the authors suggested that the various stages

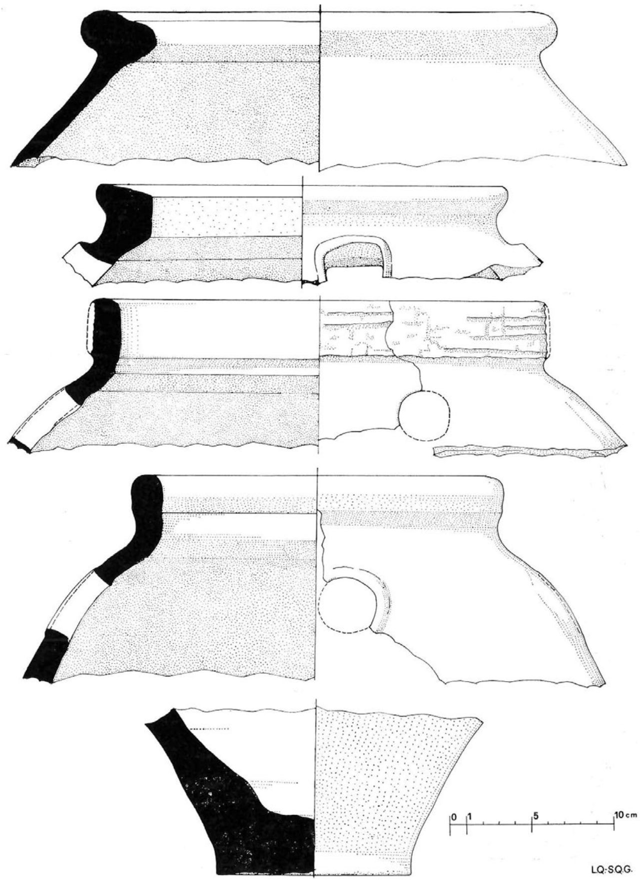

Fig. 2: Ardea, *Latium*. Photo and drawing of some *ollae* for the sulphur extraction.

of sulphur processing might have taken place here. More specifically, in the quarries/tunnels identified as sites A–B, the sulphur could have been extracted still unrefined, not separated from the gangue, the waste product usually associated with the mineral intended for use. At F the remains of basins for channelling the springs that abounded in the vicinity could be seen whilst at site G, as at D, it is likely that the procedure aimed at obtaining pure sulphur, in use until the last century, took place. The unprocessed mineral was placed in large ceramic containers with lids and tubes placed over a boiler (fig. 3, 1), and heated to 112-114°C; after liquidising, it vaporised, separating from the gangue. The sulphur fumes passed through the tubes into another container (fig. 3, 2), where they cooled and liquefied; at this point the pure sulphur was then collected in other vases or moulds, from which the cakes destined for trade could then be made (fig. 3, 3).

That the villa of Tor Caldara was built here not just to enjoy the splendid views over the Tyrrhenian Sea but above all as a control centre for the operations to extract and process sulphur, intended for a wide variety of uses, seems a fairly plausible hypothesis and indeed the continuity *in situ* of the same extraction techniques over the centuries supports this theory.

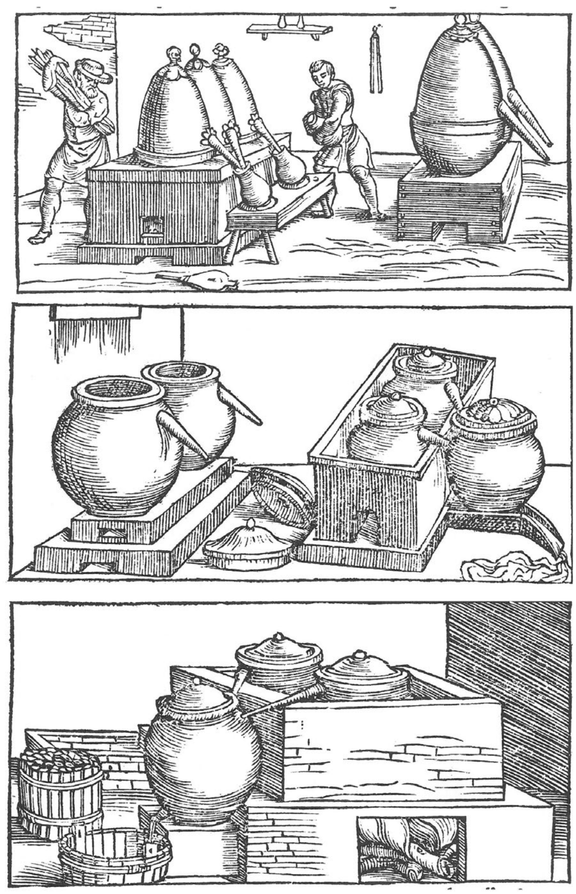

Fig. 3: The extraction process of the sulphur in some illustrations of Agricola, 1563.

Naturally, this is not an isolated instance, and it is clear that elsewhere too, where sulphur was abundant, there must have been installations of this type, mostly privately run. A representative example is the eastern area of Agrigento, famous for its wealth of springs and sulphur quarries. It has been the subject of a very recent research project devoted to studying the production of this mineral from the Hellenistic to the Byzantine period:[17] 35 sites were identified, some used for production and others of a residential type, and yet others used as a necropolis, but all lying near the springs and the sulphur quarries (fig. 4). Whilst it was already known in the 19th century that the *tegulae sulphuris* obtained using the procedure described above came from this area,[18] the project made it possible in many cases to identify the production places of these sulphur cakes, since fragments of *tegulae* identical to those already known were found directly on site. From the topographical map provided we see that in this case, too, as at Tor Caldara, there must have been residential areas, in other words *villae*, which functioned as a control and management centre for the entire production process between the II to the IV century AD, in all likelihood entrusted to slaves.

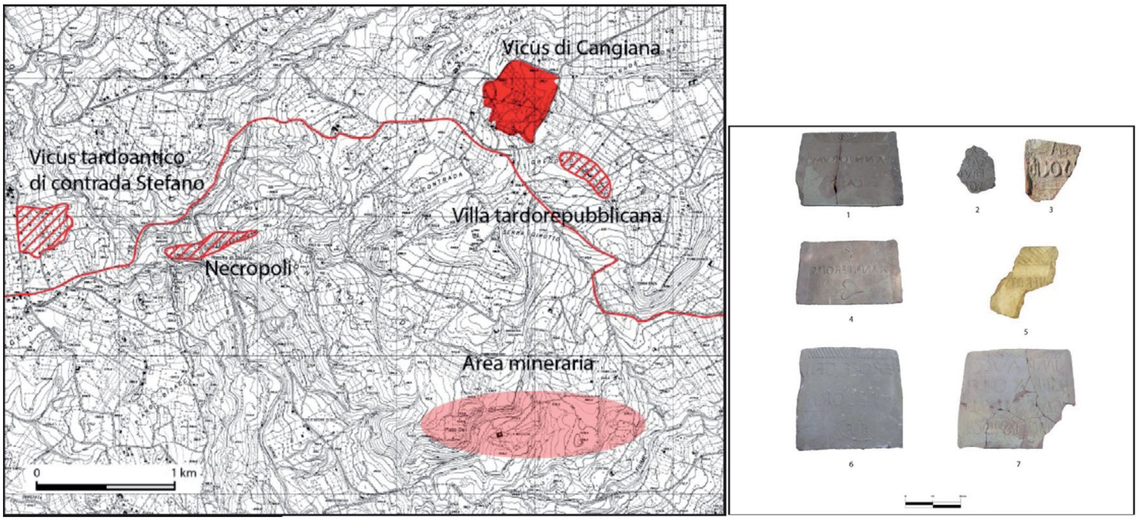

Fig. 4: Agrigento, Sicily. Topographical map of the Roman private contexts, where some *tegulae sulphuris* were found.

Archaeological Contexts for Pottery Production

Different issues with respect to those connected to the processing of sulphur emerge in the case of the identification of the chemical components derived from thermomineral waters used for the production of terra sigillata pottery and in particular of the so-called Arretine ware.[19]

As is known, this particular ceramic class became established in the area of Arezzo in the second half of the 1st century BC[20] and became extremely popular, spreading through Italy and Gaul before being partially supplanted by African red slip ware.[21]

Already in the early 20th century, some chemists from the University of Padua had suggested the presence of boric acid in the glaze of the Arretine vases,[22] undertaking a series of analyses also performed by German colleagues.[23] Even at this time it was clear that borax and boric acid were used to obtain the sheen and red slip typical of these vessels. These materials were widely available at the hydrothermal springs of Larderello, an area famous precisely for its 'borax fumaroles' and only a short distance from *Aretium* itself. It was thus proposed with a good margin of certainty that these substances came from this borax-rich region, and were brought to Arezzo along the trade networks of the metal route; at this production centre they were then mixed with other components to obtain the red slip peculiar to this ceramic class.

The Aretine workshops are archaeologically attested in various areas of the city,[24] but a certain ground plan is available only for one of them, perhaps belonged to *M. Perennius* (fig. 5). Beneath the space occupied by the church of Saint Maria in Grandi were production facilities arranged around a porticoed area A, including two basins for clay, a larger one, C (8.6 × 3.8 m, depth 1.2 m) lined with terracotta blocks, and a

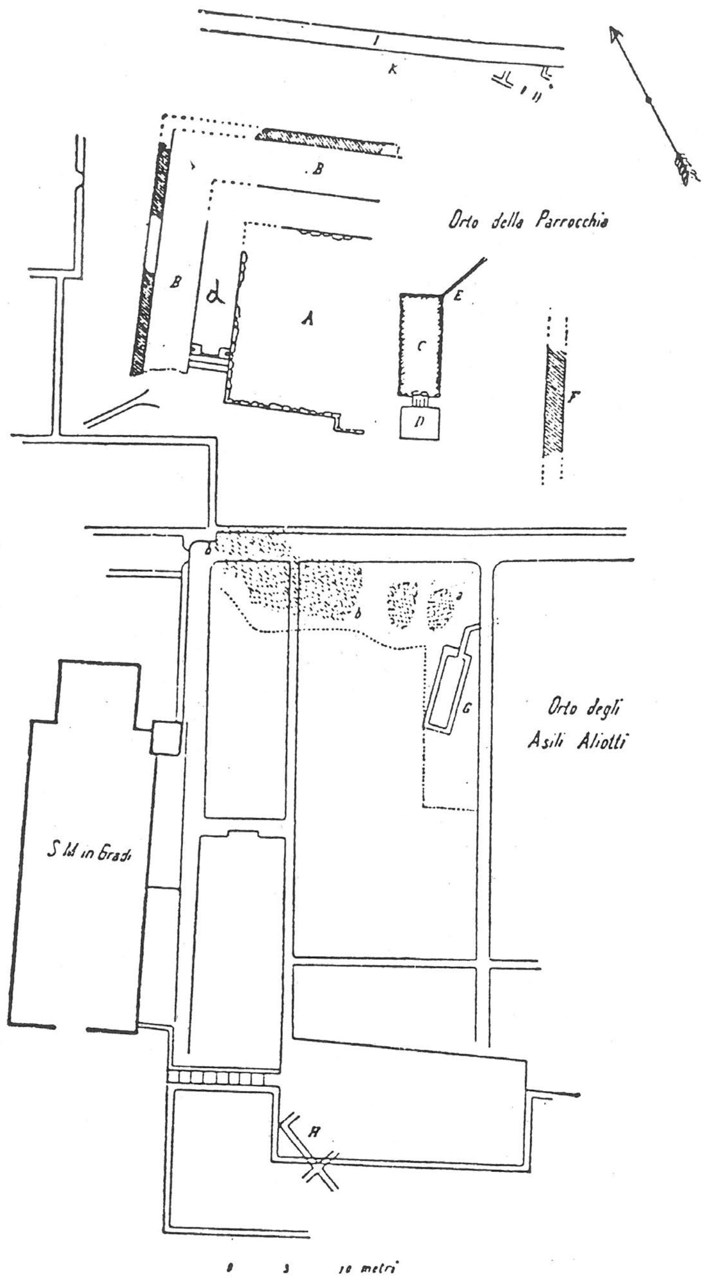

Fig. 5: *Aretium*, Tuscany. Plan of the workshop for the production of *Aretina vasa* close to a *domus*.

smaller one D (2.8 × 3.5 m) lined with plaster, and a small channel E; annexed to this first group were some rooms interpreted as the *ergastula* of the *figuli*, who worked for a *dominus* whose probable *domus* was identified nearby. Observing the same map, further south we find other basins for clay, including basin G (4.7 × 1.8 m, lined with

Fig. 6: Santa Venera-Acireale, Sicily. View of the manufacturing area near the *Thermae Xifoniae*.

concrete on the inside), near a large pottery dump marked on the plan with the letter *A*. Though the location of the kilns belonging to this facility is unknown, as they were not found during the excavation, they must have been in the immediate vicinity in order to optimise the time needed and the various production phases.

Besides the resumption of this manufacturing tradition in the modern period,[25] the use of a specific by-product such as boric acid in the slip of Arretine ware suggests that we may be able to identify other thermomineral sites with a potential artisanal vocation. Thus, for example, we can note that near Pomarance at Bagno al Morbo,[26] not far from Arezzo and Larderello, a thermomineral context of the Roman period is known that may be the *Aquae Volaterranae* shown on the *Tabula Peutingeriana*.[27] This area is rich in cold but mineralised waters, classified as rich in carbon, iron and sulphur salts, but also in gas emissions identical to those of Larderello, in other words containing borax. The structures at this site have been interpreted generically as belonging to a settlement identified in the 19th century and may also turn out to be closely connected to the production of pottery and specifically of red slip ware. This is true particularly considering that during the Middle Ages when the area hosted a flourishing ceramic industry making a brightly coloured type of pottery known as 'ingobbiato-graffito' (slipped-incised).[28]

To broaden the range of production centres that may potentially have used hydrothermal by-products, we could recall that in Sicily a late antique district where bricks were produced has been brought to light near Santa Venera-Acireale, believed to be the ancient *Thermae Xifoniae*.[29] This area, built in the vicinity of a settlement established near sulphur springs

Fig. 7: Montirone-Abano Terme, Veneto. *Rhytà* in *terra sigillata* from a Roman context.

containing radioactive bromine and iodine salts was home in the Roman period to a thermal curative facility with a small annexed temple. From the 4th century AD onwards, in an earlier Hellenistic district, a large area hosting 37 rooms connected to warehouses and three kilns was built, where bricks, pottery and tiles were made (fig. 6): it is highly likely that for manufacturing these products local clays were used, for which some basins have been identified in the immediate vicinity of the complex.

Based on the data hitherto proposed it is therefore not arbitrary to assume that at the *Aquae Patavinae*, too, in the Euganean area there may have been workshops that used the clays present there, obtained by maturing the muds from the springs containing

Fig. 8: Montirone-Abano Terme, Veneto. Vases in *terra sigillata* from a Roman context.

radioactive bromine, iodine and lithium salts that gush out, as is known, at 87°C. In this context, the mind immediately turns to the very rich ceramic deposit discovered near Abano Terme at Montirone,[30] in 1951: it is believed to have belonged to an *emporium* aimed at those seeking a cure at the *aquae* patronised by Apollo and *Aponus*, to whom various inscribed panels discovered in the vicinity were dedicated.[31] The deposit is an accumulation of numerous refined drinking vessels, including 12 glazed *rhytà* in purified clay (fig. 7), mostly with antelope heads, alongside around a hundred fine-walled beakers in a gray or orange fabric (fig. 8), signed by some known potters of the early imperial period (including *Aco*, *Norbanus*, *Clemens* etc.).

The only information on structures and infrastructure found in the vicinity of the deposit are those noted in 1986, when walls and amphorae used for drainage were discovered.[32] Perhaps more interesting are the two plastered basins found just to the east at the 'Trieste property' in 1874:[33] one was fairly large (22.7 × 10.05 m) and one smaller (6 × 2.4 m), both accessed by steps, dating, like the vases in the deposit, to the Augustan period. Whilst some scholars believe that these basins may have been used for bathing, although without any certain evidence of this, a different part of the same context yielded other artefacts (some inscriptions, a trachyte weight, an antefix, two male busts, alongside materials belonging to a funerary context) that suggest this sector should be identified as a unitary context.

Some scholars believe that it should be interpreted as a funerary area,[34] whilst in my opinion it seems more likely that this was a residential and artisanal district like that at Arezzo mentioned above. According to this second hypothesis, the area may have developed precisely thanks to the production of objects to be sold to the patrons of the baths, such as the aforementioned vases and beakers, which may have been used for drinking the thermal waters and/or for dedication to the divinities presiding over these waters, *Aponus* and Apollo. The presence of busts of high-ranking individuals like that of an old man, now lost, alongside the antefixes might suggest that near the basins and the *emporium* there was a villa belonging to the owner as at Arezzo and Agrigento, equipped with the usual decorations such as the *imagines maiorum*, but also serving as a control centre for the economic activities of the rich Euganean area.

It would thus be interesting to undertake chemical and physical analyses of the clays used for the vases from Montirone, to clarify whether these were made *in situ* by specialised artisans or elsewhere – which would obviously make little economic sense.

Concluding Remarks

Examining the use of some thermal by-products in the Roman period on the basis of the archaeological and literary sources, where possible compared with the treatises of the modern period, has made it possible to pinpoint the potential offered by hydrothermal resources aside from their better known and more studied use for curative purposes. It goes without saying that numerous ancient thermal spas were and continued to be famous and renowned for the healing properties of their waters, but the importance of understanding and identifying the settlement system around the *aquae* is also evident.

The latter certainly consisted of hotels, residential or rustic villas, but – I believe – also of production facilities, including those structures and infrastructure that exploited the by-products of which an initial sample was discussed here. Ongoing research will certainly provide opportunities to broaden our approach and deal in greater detail with the wide-ranging production potential of these natural resources. However, the information set out here already seems to open up unprecedented prospects for interdisciplinary research, combining economic, market and artisanal motivations but also new interpretations of very well known archaeological artefacts.

Notes

[1] Annibaletto et al. 2014; Peréx Agorreta – Alaix i Miró 2017; Guérin-Beauvois 2015; Scheid et al. 2015; Matilla Séiquer – Gonzálo Soutelo 2017.

[2] For the Montegrotto Terme context, see Bassani et al. 2011; Bassani et al. 2012; Bassani et al. 2013.

[3] See the PhD theses by M. Marcato (Marcato 2014–2016) and C. Zanetti (Zanetti 2014–2016).

[4] Annibaletto – Bassani 2013; Ghedini – Bassani 2014.

[5] Annibaletto – Basso 2014.

[6] Annibaletto 2014.

[7] See the works on the subject by the present author, with ample reference bibliography (Bassani M. 2011–2017); cfr. also Costa Palahí – Vivó 2011.

[8] Several articles on all these topics in the book edited by Annibaletto et al. 2014.

[9] Information in Burgassi 2005; Bassani M. 2016a; Bassani M. 2017a; for the protohistorical period cfr. Grifoni Cremonesi 2005; for the medieval period cfr. Dallai – Francovich 2005. The reference volume on mines and metallurgy in the Greek and Roman world is Healy 1993 (Italian translation).

[10] Pola et al. 2014.

[11] See above, note 1.

[12] Bassani M. 2011.

[13] Bassani M. 2016b. News recently emerged of the discovery, by the Nucleo dei Carabinieri per la Tutela del Patrimonio Archeologico, of clandestine excavations inside the reserve, stopped in a timely fashion, <http://www.romatoday.it/cronaca/furti-villa-romana-tor-caldara-.html> (26.08.2020).

[14] On the excavation Quilici – Quilici Gigli 1984; for an initial reconsideration Bassani M. 2016b.

[15] Agricola, *De re metallica*, 1563 (Macini – Mesini 1994); Biringuccio, *De la pirotechnia*, 1540 (Carugo 1977).

[16] Pace 1935, I, 392–399.

[17] Zambito 2014.

[18] Salina 1900; Salina 1901.

[19] Goudineau 1968; Pucci 1985; Burgassi 2005.

[20] The principal study of the Roman vases produced in the Arezzo area is Paturzo 1996. It is thought that there were around 100 workshops, large and small, at Arezzo. For a very detailed overview of the various types of terra sigillata, cfr. EAA, s.v. Aretini, vasi <http://www.treccani.it/enciclopedia/terra-sigillata_%28Enciclopedia-dell%27-Arte-Antica%29/> (26.08.2020).

[21] For a general overview cf. Comfort – Paribeni 1962.

[22] Nasini 1939; it is worth recalling that Nasini began his research on Larderello when working at Padua and continued these subsequently, after moving to Pisa. For a biography of this famous lecturer in chemistry cfr. Bassani A. 2009, 418–450, in particular 448–450 for his research on Larderello.
[23] Miller 1916.
[24] Paturzo 1996, 104–107; Paturzo 1997, 382–384.
[25] According to Vasari, only a few people in the late medieval and modern period knew the secret to recreating the sheen of this particular type of Roman pottery: Vasari 1906, 557–558 (cited in Burgassi 2005, 76 and note 7, with bibliographical references).
[26] Chellini 2002, 177–178; Groppi 2006.
[27] Ghedini 2014, 113.
[28] Burgassi 2005, 78.
[29] Cfr. the website <https://termediacireale.wordpress.com/storia/enciclopedia-dellarte-antica-treccani/> (26.08.2020); See also Braciforti et al. 2006; Amari 2007.
[30] Lavizzari Pedrazzini 1995; for an analysis of the area of Abano Terme cfr. Zanovello 2012.
[31] Zanovello et al. 2010, with ample preceding bibliography.
[32] Bressan – Bonini 2012, 93, AT 14.
[33] Bressan – Bonini 2012, 94, AT 20.
[34] Bressan – Bonini 2012, 94, with preceding references.

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Fig. 1: Quilici – Quilici Gigli 1984, 234 fig. 4. – Fig. 2: Quilici – Quilici Gigli 1984, 240 fig. 13; 243 fig. 16. – Fig. 3: Carugo 1977, images at the cartae 25v, 26v, 27. – Fig. 4: Zambito 2014b, fig. 2. 3. – Fig. 5: Paturzo 1996, 104 fig. 16. – Fig. 6: Branciforti et al. 2006, 94 fig. 11. – Fig. 7: Lavizzari Pedrazzini 1995, 156. – Fig. 8: Lavizzari Pedrazzini 1995, 149.

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