ACTA IMEKO
ISSN: 2221-870X
March 2022, Volume 11, Number 1, 1 - 10

Calculating vessel capacity from the Neolithic sites of Lugo di Grezzana (VR) and Riparo Gaban (TN) through 3D graphics software

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ABSTRACT
This paper reports new data about the estimation of the volumetric capacity of ceramic vessels from the Neolithic sites of Lugo di Grezzana (Verona, Italy) and Riparo Gaban (Trento, Italy). The methodological protocol is based on a free and open source 3D computer graphics software, called Blender®. The estimate of the volumetric capacity has been relied from the graphic elaboration of the archaeology drawing of the artifacts. Through the calculation of volume has been possible to obtain an estimation of the total capacity of the vessels, proposing two types of content. Subsequently, the volumetric data was related to diameter/height ratio of each ceramic vessel, in order to define a range of variability in each typological class. Data from both sites were later compared, highlighted for the most part of them a specific distribution that could be a consequence of different functional uses and/or cultural models. This paper concludes the preliminary results presented at the 2020 IMEKO TC4 International Conference on Metrology and Archaeology for Cultural Heritage.

Section: RESEARCH PAPER

Keywords: Vessel capacity; Ceramics; 3D models; Blender; Neolithic

Citation: Andrea Tavella, Marika Ciela, Paolo Chistè, Annaluisa Pedrotti, Calculating vessel capacity from the Neolithic sites of Lugo di Grezzana (VR) and Riparo Gaban (TN) through 3D graphics software, Acta IMEKO, vol. 11, no. 1, article 7, March 2022, identifier: IMEKO-ACTA-11 (2022)-01-07

Section Editor: Fabio Santaniello, University of Trento, Italy

Received March 7, 2021; **In final form** February 23, 2022; **Published** March 2022

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1. THE CERAMIC RECORD

The study takes into account ceramic finds from the Neolithic sites of Lugo di Grezzana and Riparo Gaban. Both sites show a frequentation during Early Neolithic and play a key role for the understanding of Neolithization process in the northern Italy (Figure 1).

1.1 Lugo di Grezzana (VR)

The area to the south of the small town of Lugo di Grezzana, called locality Campagne, is situated over a river terrace (300 m above sea level) along Valpantena, a short prealpine valley located in the Lessini Mountains [1]. The discovery of the site dates back to 1990 by Fernando Zanini and Giorgio Chelidonio. The area has been the object, since the early nineties, of systematic research undertaken by the Archaeological Heritage of Veneto Region, in collaboration with the University of Trento since 1996 (B. Bagolini Laboratory – LaBAAF) up until 2005 [2]. The first evidence is dated in the middle of the 6th millennium BC cal, while an intense occupation of the area is dated between 5300 – 5050 BC Cal [3].

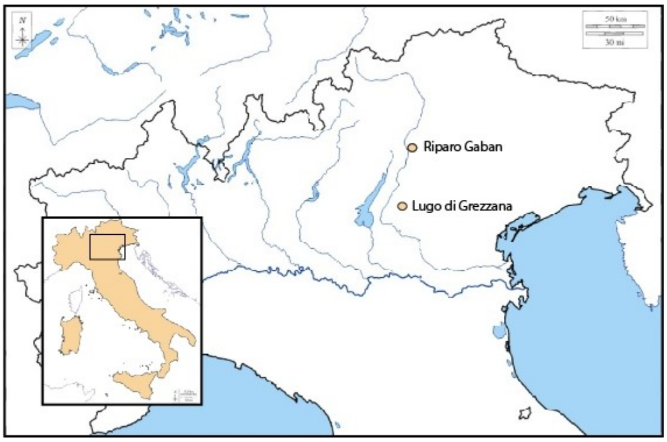

Figure 1. The localization of Lugo di Grezzana (Verona, Italy) and Riparo Gaban (Trento, Italy).

Figure 2. Vessel from the Neolithic site of Lugo di Grezzana (Photo P. Chistè – LaBAAF) [2].

Based on material culture [2]-[5], the site is mainly attributed to Fiorano, which is present in northern Italy during the Early Neolithic and shows a typical homogeneity in vessels typology. Jug is possibly one of the most distinctive shapes of the Fiorano culture (Figure 2) and is often imported into contemporary cultures. Although, numerous elements have been permitted to underline influences from other contexts such as Vhò group, Adriatic Impressed Ware and Catignano cultures [2], mainly due to the supply of Lessinian flint. The latter, thanks to its high-quality, becomes the object of exchange par excellence and a sort of common denominator between the various groups of the Early Neolithic in northern Italy, between the middle of the 6th and the beginning of the 5th millennium BC [3], [6].

Around 5000 BC cal, the occupation of the settlement seems to show a temporary interruption with the occurrence of colluvial episodes, while the last Neolithic occupation, scanty represented, is attested between 4900 and 4800 BC cal. During this period, the early geometric-linear style of Square Mouthed Pottery culture is already widespread in the northern Italy, the latter attested within the site in contemporary with later aspects of Fiorano culture [3].

1.2 Riparo Gaban (TN)

The site of Riparo Gaban is located at Piazzina di Martignano, in a small hanging valley that runs parallel to the left side of Adige Valley (270 metres above sea level), a few kilometres north-west of Trento [7]. The site, identified as a rock-shelter, has been discovered in 1970 by a group of local amateurs as a part of the palaeoethological activities of the Museo Tridentino di Scienze Naturali. The excavations have been conducted under the technical direction of Bernardino Bagolini from 1972 to 1981, by Alberto Broglio and Stefan K. Kozlowski from 1982 to 1985 for the Mesolithic phases [8], [9]. The site is characterised by a complex stratigraphic evolution from Mesolithic to Middle Bronze Age, with a stratigraphic continuity between Castelnovian Mesolithic and local Early Neolithic deposits, these latter dated between the end of 6th and the beginning of 5th millennium BC. The site is one of the main pieces of evidence for the understanding of first Neolithic evidences in Trentino Alto-Adige and gives its name to the cultural group presents in the Adige Valley during this period.

Unlike Lugo di Grezzana and generally to the Fiorano culture, the main aspect of the Gaban group appears to be a strong Mesolithic component. Especially observed in the lithic and bone industries, with extraordinary examples of mobiliary art that gives to the site, not only the appearance of a simple rock-shelter but probably also a magical-religious connotation [8], [10].

From a typological point of view, the Gaban group, despite a markedly autonomous framework, presents several connections with others cultural groups of the Early Neolithic, in particular with Isolino and Vhò groups, and to a lesser extent with Fiorano [11]. About the material culture identified at Riparo Gaban (Figure 3), the stratigraphic evolution allowed to observe an oldest phase characterised by a strong presence of impressed ware and a more recent phase where scratched pottery is more attested [11].

The Neolithic occupation is interrupted as from 4700 BC cal, documenting a possible phase of abandonment of the rock-shelter up to 2700 BC cal [8].

2. THE CALCULATION OF VOLUMETRIC CAPACITY

The volumetric estimate of a vessel can be calculated mainly through three types of volume calculation: direct measurements, two-dimensional geometrical methods (manual calculation), and computer-assisted methods, these latter based on 3D models (automatic calculation).

Direct measurements are taken from the container and allow directly to obtain the volumetric capacity. These methods involve filling the vessel with a suitable material able to adapt to the internal profile. However, they cannot be applied to the entire ceramic record, both because usually a limited percentage of vessels from archaeological excavations are complete or partially reconstructed, and also for conservation issues [12]-[14].

The second method, about manual calculation, is based on the decomposition of the vessel volume into basic forms (spheres, cylinders, or truncated cones) and calculated through mathematical formulae [15]-[22]. The archaeological drawing represents the starting point of this method and, unlike direct measurements, does not require the availability of the archaeological find. However, the degree of approximation represents a negative aspect, as the complex form of the vessel is transformed into simplified form, although this depends on the geometric shape used.

The last method, computer-assisted, is focused on 3D models. Here too, the volumetric capacity is obtained through measurements directly on the archaeological drawings, exploiting the principle of symmetry. Different software can be used, such as: AutoCAD®, Rhinoceros™ and Blender® [14], [23]. In addition, other suitable programs are available as Kotyle© [24] and web applications like Capacity [12], [25], [26]. In this study, the 3D graphics program of choice is Blender® [27] since it is free and open source, which allows the users to generate extensions in order to improve it. The estimate of the volumetric calculation was relied on the *3D-Print Toolbox* extension, although different *add-ons* are known to be effective as well [23].

Regarding the study of ceramic record, it is important to refer to the digitalization in 3D of some pottery mentioned in this paper through photogrammetry. This work was carried out at TeFALab (Laboratorio di Tecniche Fotografiche Avanzate, unit

Figure 3. Vessel from the Neolithic site of Riparo Gaban (Photo E. Turco) [10].

of LaBAAF, University of Trento) under the technical direction of Paolo Chistè.

About the study of volumetric capacity, are only present preliminary results for the site of Lugo di Grezzana [28], while for Riparo Gaban this aspect of research has not been studied yet. At the present time, a systematic analysis that evaluates the metric criteria of the ceramics of the Fiorano culture has not yet been carried out [29] and more. However, for the Neolithic of northern Italy there is a typological classification of the vessels that distinguishes their morphology in relation to the profile, the diameter/height ratio ($\varnothing/h$), and the size of the mouth [30]. Nevertheless, this classification does not include the volumetric capacity parameter.

3. MATERIAL AND METHODS

The methodological protocol was applied to a selection of 48 archaeological drawing, of which 35 from Lugo di Grezzana and 13 from Riparo Gaban (Figure 6 and Figure 7). The sample analysed was chosen taking into consideration the typological classification. Out of the total samples, 26 drawings illustrate whole artifacts, with a continuous profile from the rim to the bottom of the vessel (Lugo di Grezzana: 15 samples; Riparo Gaban: 11 samples), while the other are only partially preserved. For the latter, as in the previous study [28], it was therefore necessary to hypothesize the profile and the height of the vessel. To carry out this operation, the fragmented samples were integrated through the study of whole ceramic vessels belonging to the same typological class (Figure 4).

For both groups, and especially the latter, it is essential to keep in mind that the capacity estimate deduced from archaeological drawings has a different degree of accuracy. The manual drawing is based on one radial section and represents a two-dimensional shape of the vessel not taking into account the possible variations in the three-dimensional shape of the object [31].

The development of the operating methodology is based on three minimum requirements that ceramics and designs must have:

- Availability of diameter and internal profile;
- Scale of representation;
- High-resolution drawing (d.p.i.);

The calculation of the volumetric capacity is carried out by importing each drawing into the 3D graphic program (Blender version 2.92), providing the exact graphic resolution of the file (d.p.i.). This step is necessary in order to avoid any change in the original dimensions of the imported drawing that would therefore entail an incorrect estimate of the volume. Subsequently it is generated a curve (*Bezier*), which is modified along the X and Y axes and divided into several segments, in order to trace the underlying drawing. After obtaining a 2D profile, it is necessary generate a line (*Path*), which will correspond with the rotation axis of the curve itself and with the midline of the archaeological drawing. Once the rotation axis is fixed, the curve can be rotated 360 degrees.

This procedure requires to define some options, namely: the Cartesian axis to which the curve is oriented, the object around which the rotation takes place and lastly the number of *segments* the revolution is divided into (a greater number of these entail corresponds to a better graphic resolution and consequently a more accurate estimate of the volume).

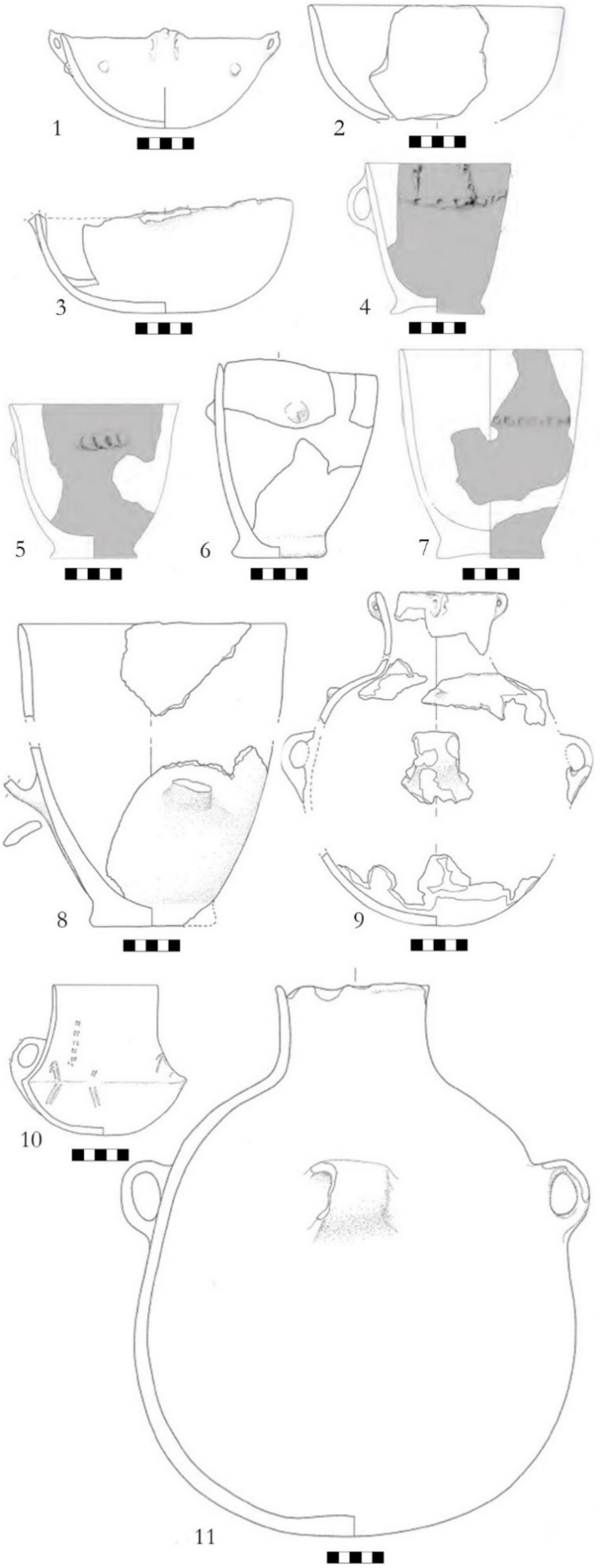

Figure 4. Typological table with some samples used to hypothesize the profile and the height of the vessels: 1-3, 6, 8-11 from Lugo di Romagna (RA) [32]; 4-5, 7 from Vhò di Piadena-Campo Ceresole (CR) [33].

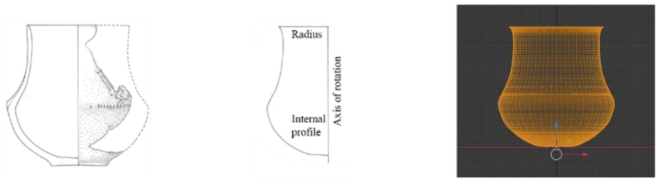

Figure 5. Summary scheme of the operating methodology performed with Blender®.

The essential step for obtaining the volume is the closure of the solid at the rim and at the base. Once the solid is closed, the calculation of the volumetric capacity is performed automatically using the *add-on*: *3D-Print Toolbox* (available since version 2.67, released in May 2013), which volume is expressed in cm3 (Figure 5).

The validity of the procedure was previously established during the formulation of the method, through the graphic reproduction and the volumetric calculation of a cylinder of known dimensions (r = 5 cm; h = 20 cm). This procedure allowed to calculate the absolute and relative error in the method developed, taking into account the tolerance. The latter is characterised by different causes such as: the inherent uncertainty regarding the measured object, the conservation status, the operator, the procedure and the measuring instrument used. Taking these issues into account, it was calculated a tolerance of about $\pm$ 1 mm.

$$Absolute\ Error\ (EA) = \frac{(Vol_{\max} - Vol_{\min})}{2} = 70.6889\ cm^3$$

$$Relative\ Error\ (RE) = \frac{EA}{Vol_{\text{avg}}} = 0.0449$$

$$Percentage\ Error\ (PE) = RE\ \times 100\ \% = 4.49\ \%\ .$$

The methodological approach was subsequently extended, considering two hypothetical types of contents, a liquid and a solid one. As to what concerns the estimate of the capacity, it was treated converting the measure from cm^3 to ml (1 cm^3 = 1 ml). Instead, in the case of solids contents was calculated the weight (grams) of three types of cereals such as: whole barley, emmer and naked wheats, selected accordingly to the data collected from archaeobotanical analysis carried out for the site of Lugo di Grezzana [34]. The weights were estimated in relation to the bulk density of each kind of cereal (whole barley 0.61 ÷ 0.69 g/ml, emmer 0.47 g/ml e naked wheats 0.54 g/ml) [35], [36] and the volumes of the containers, according to the following formula:

$$Weight = Bulk\ density\ \times Volume\ .$$

Lastly, metrical analysis were carried out through the correlation of the maximum volumetric capacity (cm^3), diameter and height ratio (Ø/ h), and typology [30].

Table 1. Summary of results from Lugo di Grezzana (L.G.) and Riparo Gaban (R.G.). Legend: Bw. = Bowl; Cp. = Cup; H. V. = Handle Vessel; Jg. = Jug; L.B. = Large Bowl; Mn. = Miniaturistic; N.V. = Necked Vessel; Pt. = Pot; T.V. = Truncate cone-shaped vessel; * = partially preserved.

Samples	Estimate Liquid Content (ml)	Estimate Solid Content (g)				
		Whole Barley		Emmer	Naked Wheats	Ø/H Ratio
L.G. Bw. 1*	545	332	376	256	294	2,45
L.G. Bw. 2*	1014	619	700	477	548	3,03
L.G. Bw. 3*	1680	1025	1159	789	907	2,39
L.G. Bw. 4*	3755	2290	2591	1765	2028	1,97
L.G. L.B. 1*	5276	3218	3640	2480	2849	3,23
L.G. L.B. 2	6959	4245	4802	3271	3758	2,74
L.G. L.B. 3*	4814	2936	3322	2263	2599	2,42
L.G. L.B. 4*	6763	4125	4666	3178	3652	2,18
L.G. T.V. 1	5646	3444	3895	2653	3049	0,92
L.G. T.V. 2*	17307	10557	11942	8134	9346	1,08
L.G. T.V. 3	2967	1810	2047	1395	1602	0,97
L.G. T.V. 4*	1329	811	917	625	718	0,77
L.G. T.V. 5*	5941	3624	4099	2792	3208	0,82
L.G. T.V. 6	944	576	652	444	510	1,00
L.G. T.V. 7	3961	2416	2733	1862	2139	0,80
L.G. T.V. 8*	5235	3193	3612	2460	2827	0,87
L.G. T.V. 9*	750	458	518	353	405	1,08
L.G. T.V. 10*	1521	928	1049	715	821	0,84
L.G. T.V. 11*	2112	1288	1457	993	1140	0,96
L.G. H.V. 1	925	564	638	435	499	1,16
L.G. Jg. 1	413	252	285	194	223	0,86
L.G. Jg. 2	1825	1114	1260	858	986	0,83
L.G. Jg. 3	772	471	533	363	417	0,83
L.G. Jg. 4	839	512	579	394	453	0,74
L.G. Jg. 5*	653	398	451	307	353	0,88
L.G. Jg. 6*	889	542	614	418	480	0,83
L.G. Jg. 7*	1508	920	1040	709	814	0,87
L.G. Jg. 8*	2022	1234	1395	951	1092	0,85
L.G. N.V. 1*	6054	3693	4177	2845	3269	0,47
L.G. N.V. 2*	13378	8161	9231	6288	7224	0,26
L.G. Ld. 1	38	23	27	18	21	1,84
L.G. Mn. 1	53	33	37	25	29	0,76
L.G. Mn. 2	158	97	109	74	86	2,24
L.G. Mn. 3	59	36	41	28	32	1,14
L.G. Mn. 4	79	48	54	37	42	2,50
R.G. Bw. 1	2858	1743	1972	1343	1543	1,52
R.G. T.V. 1*	2894	1765	1997	1360	1563	0,97
R.G. T.V. 2	17135	10452	11823	8053	9253	1,11
R.G. T.V. 3	1589	969	1097	747	858	1,18
R.G. T.V. 4*	1290	787	890	606	697	0,82
R.G. Cp. 1	397	242	274	186	214	1,19
R.G. Cp. 2	403	246	278	190	218	1,10
R.G. Cp. 3	764	466	527	359	413	1,38
R.G. Cp. 4	1406	858	970	661	759	0,96
R.G. Cp. 5	2023	1234	1396	951	1092	1,02
R.G. Jg. 1	645	393	445	303	348	0,82
R.G. Pt. 1	1668	1017	1151	784	901	0,52

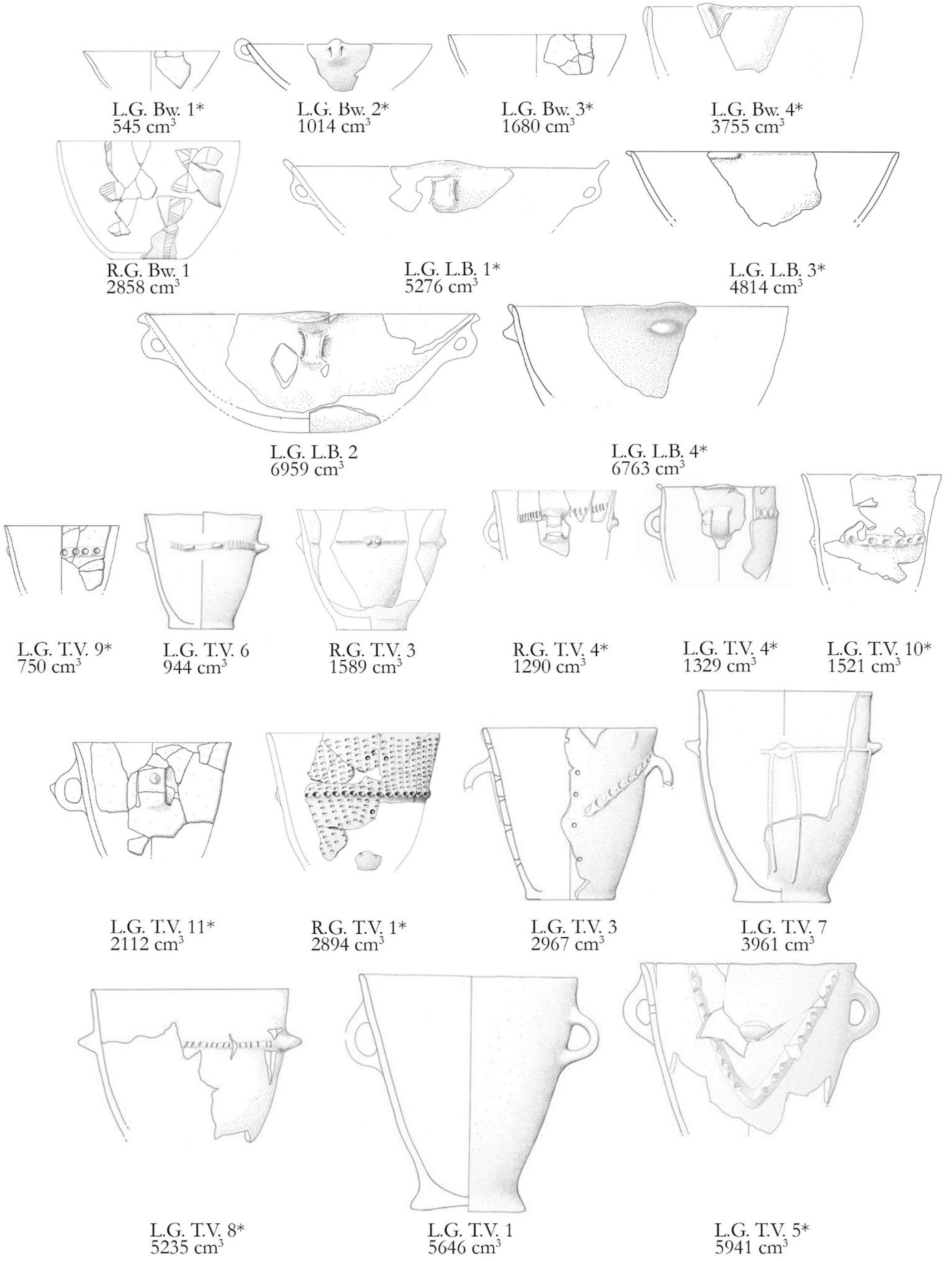

Figure 6. Typological table of the samples analysed during the study from Lugo di Grezzana (L.G.) and Riparo Gaban (R.G.). Scale drawing 1:6. Legend: Bw. = Bowl; L.B. = Large Bowl; T.V. = Truncate cone-shaped vessel; * = partially preserved.

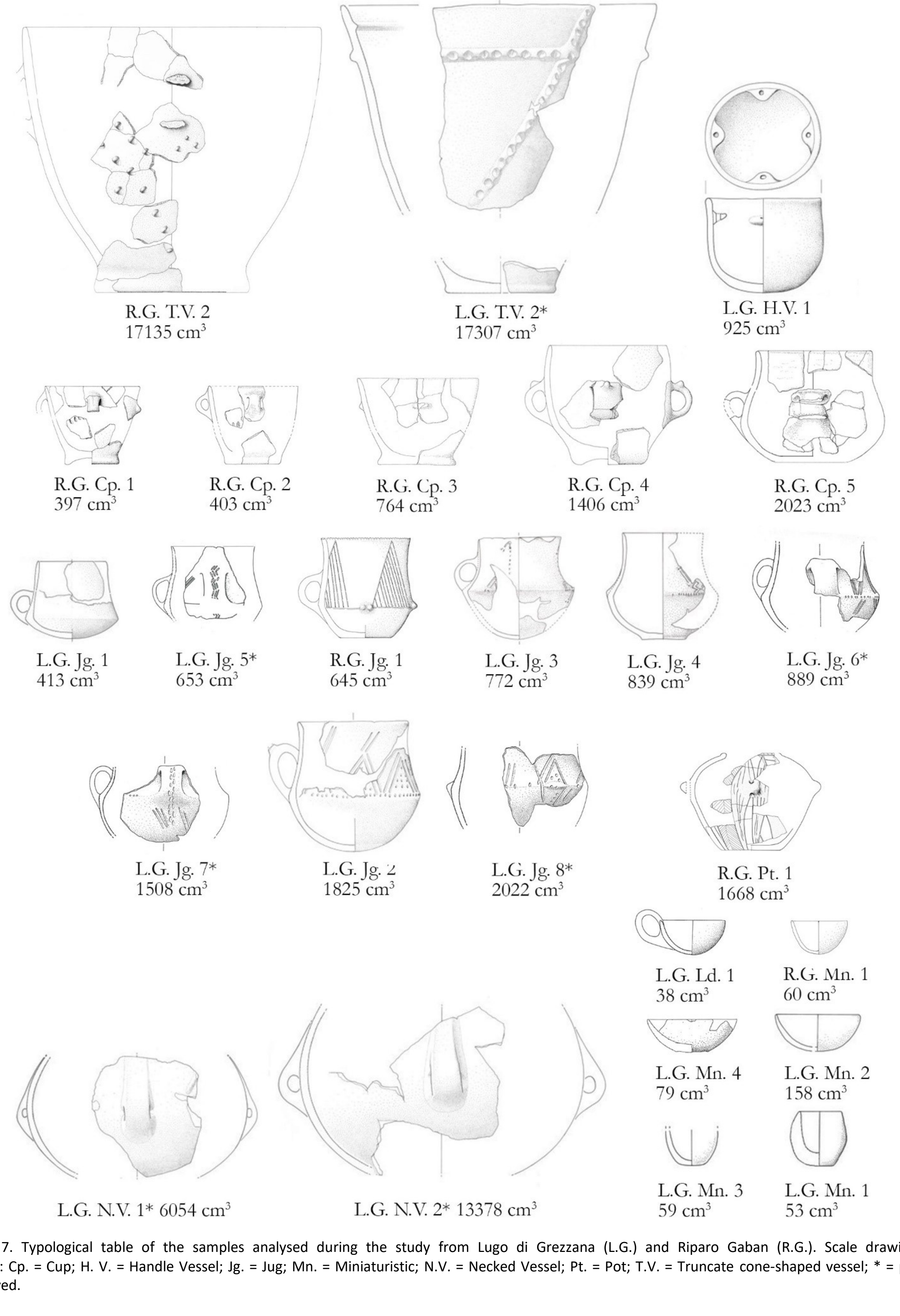

Figure 7. Typological table of the samples analysed during the study from Lugo di Grezzana (L.G.) and Riparo Gaban (R.G.). Scale drawing 1:6. Legend: Cp. = Cup; H. V. = Handle Vessel; Jg. = Jug; Mn. = Miniaturistic; N.V. = Necked Vessel; Pt. = Pot; T.V. = Truncate cone-shaped vessel; * = partially preserved.

Table 2. Summary of results organised for typological class.

Typological classification	Total					Lugo di Grezzana					Riparo Gaban				
	Samples	Samples partially preserved	Estimate Liquid Content (ml)	Estimate Solid Content (g)	Ø/H Ratio	Samples	Samples partially preserved	Estimate Liquid Content (ml)	Estimate Solid Content (g)	Ø/H Ratio	Samples	Samples partially preserved	Estimate Liquid Content (ml)	Estimate Solid Content (g)	Ø/H Ratio
Bowl	5	4	545 ÷ 3755	256 ÷ 2591	1,52 ÷ 3,03	4	4	545 ÷ 3755	256 ÷ 2591	1,97 ÷ 3,03	1	-	2858	1343 ÷ 1972	1,52
Large Bowl	4	3	4814 ÷ 6959	2263 ÷ 4802	2,18 ÷ 3,23	4	3	4814 ÷ 6959	2263 ÷ 4802	2,18 ÷ 3,23	-	-	-	-	-
Truncate cone-shaped vessel	15	9	750 ÷ 17307	353 ÷ 11942	0,77 ÷ 1,18	11	7	750 ÷ 17307	353 ÷ 11942	0,77 ÷ 1,08	4	2	1290 ÷ 17135	606 ÷ 11823	0,82 ÷ 1,18
Internal Handles Vessel	1	-	925	435 ÷ 638	1,16	1	-	925	435 ÷ 638	1,16	-	-	-	-	-
Mug	5	-	397 ÷ 2023	186 ÷ 1396	0,96 ÷ 1,38	-	-	-	-	-	5	-	397 ÷ 2023	186 ÷ 1396	0,96 ÷ 1,38
Jug	9	4	413 ÷ 2022	194 ÷ 1395	0,74 ÷ 0,88	8	4	413 ÷ 2022	194 ÷ 1395	0,74 ÷ 0,88	1	-	645	303 ÷ 445	0,82
Pot	1	-	1668	784 ÷ 1151	0,52	-	-	-	-	-	1	-	1668	784 ÷ 1151	0,52
Necked Vessel	2	2	6054 ÷ 13378	2845 ÷ 9231	0,26 ÷ 0,47	2	2	6054 ÷ 13378	2845 ÷ 9231	0,26 ÷ 0,47	-	-	-	-	-
Ladle	1	-	38	18 ÷ 27	1,84	1	-	38	18 ÷ 27	1,84	-	-	-	-	-
Miniaturistic	5	-	53 ÷ 158	25 ÷ 109	0,76 ÷ 2,5	4	-	53 ÷ 158	25 ÷ 109	0,76 ÷ 2,5	1	-	60	28 ÷ 41	1,58

4. RESULTS

The methodological approach allowed to provide an estimate of the capacity (ml) and the weight of different contents (g). At the same time, it was possible to correlate the values determined by the computer-assisted calculations with the ratio between diameter and height (Table 1), distinguishing them based on typology[1] (Table 2). The elaboration of the data took place through the compilation of a scatter plot, reporting the volumetric capacity in the X axis and the $\varnothing/h$ ratio in the Y axis (Figure 8).

From a volumetric point of view, in either case the same degree of variation is observed, where the maximum limit is about 17,000 cm^3 and is represented by two truncate cone-shaped vessels (L.G. T.V. 8*; R.G. T.V. 2). At the same time, however, the distribution of the samples is different. In the case of Riparo Gaban, almost all samples (12 out of 13) have a volumetric capacity lower than 3000 cm^3, while for the site of Lugo di Grezzana this aspect is found in two-third of the samples (23 out of 35), showing a wider volumetric variability (Figure 8). A similar distribution is observed for the $\varnothing/h$ ratio, which is wider for Lugo di Grezzana (0.26 ÷ 3.23) than Riparo Gaban (0.52 ÷ 1.58). These dissimilarities are due to the absence of some ceramic forms (large bowls, necked vessels) or the presence in a smaller percentage (bowls, truncate cone-shaped vessels) in the dataset of Riparo Gaban.

For some typological classes, better represented, it was possible to make a comparison of the samples between the two investigated sites (Table 2).

Bowls: represented by 5 samples (4 of which are partially reconstructed). The ceramic samples are characterised by a volume between 545 and 3755 ml, containing between 256 and 2591 g of solid content and a $\varnothing/h$ ratio between 1.52 and 3.03. Although only one samples comes from Riparo Gaban and most of the volumes are reconstructed, there is a distinction on the basis of $\varnothing/h$ ratio, estimated between 1.97 and 3.03 for Lugo di Grezzana, compared to a lower value for Riparo Gaban equal to 1,52.

Jugs: represented by 9 samples (4 of which are partially reconstructed). The ceramic samples are characterised by a volume between 413 and 2022 ml, containing between 194 and 1395 g of solid content and a $\varnothing/h$ ratio between 0.74 and 0.88. Although most of samples comes from Lugo di Grezzana, a limited variability both on the volumetric data and in particular about $\varnothing/h$ ratio is observed. The lower range of $\varnothing/h$ ratio allowed to identify jugs as the ceramic shape with the highest degree of homogeneity compared to the other typological classes.

Truncate cone-shaped vessels: represented by 15 samples (9 of which are partially reconstructed). The ceramic samples are characterised by a volume between 750 and 17307 ml, containing between 353 and 11942 g of solid content and a $\varnothing/h$ ratio

[1] In this study, the distinction between jugs and mugs follows the typological classification defined in Banchieri et al. 1999 [30].

between 0.77 and 1.18. Both datasets are characterised by a homogeneity about volumetric capacity (Lugo di Grezzana: 750 ÷ 17307 ml, 353 ÷ 11942 g; Riparo Gaban: 1290 ÷ 17135 ml, 606 ÷ 11823 g) and $\varnothing/h$ ratio (Lugo di Grezzana: 0.77 ÷ 1.08; Riparo Gaban: 0.82 ÷ 1.18).

Miniaturistic forms: represented by 6 samples. The ceramic samples are characterised by a volume between 53 and 158 ml, containing between 25 and 109 g of solid content and a $\varnothing/h$ ratio between 0.76 and 2.5. The dataset is represented by different ceramic shapes, with a wide variability of $\varnothing/h$ ratio and only associated for the limited dimensions.

5. DISCUSSION

The methodological protocol has led to obtain an analysis of the volumetric capacity of a wide selection of samples, correlating the volumetric data to diameter/height ratio and typological class of each ceramic vessel. Compared to the previous study [28], the increase in the number of samples allowed to provide further information on individual typological class, especially in those most attested such as: bowls, large bowls, truncate cone-shaped vessels, cups, jugs and miniaturistic forms.

The different distribution of the ceramic assemblages (Figure 8) highlighted a wider distribution of samples from Lugo di Grezzana both on the volumetric estimates (mainly within 6000 cm³) and in the $\varnothing/h$ ratio (between 0.26 and 3.23). While in the case of Riparo Gaban, both the volumetric range (mainly within 3000 cm³) and the $\varnothing/h$ ratio (between 0.56 and 1.58) represent a lower variability.

The different distribution could depend on different reasons, both due to a poor conservation of some typological classes (e.g. necked vessels, bowls and large bowls), not allowing an estimate of the volume, and due to a different connotation of Riparo Gaban compared to the settlement of Lugo di Grezzana. This later characterised by numerous structural complexes [3], [37], [38], as well as a larger number of ceramic finds.

About the distribution of each typological class in relation to the parameters examined, for the most part of them it was possible to highlight a specific distribution, according to four trends:

- Limited volumetric range and limited $\varnothing/h$ ratio (jugs, mugs);
- Limited volumetric range and wide $\varnothing/h$ ratio (miniaturistic forms);
- Wide volumetric range and limited $\varnothing/h$ ratio (necked vessels, truncate cone-shaped vessels);
- Wide volumetric range and wide $\varnothing/h$ ratio (bowls, large bowls);

For each typological class, the greater or lesser volumetric capacity and $\varnothing/h$ ratio could provide new information about the research. For instance the case of jugs, where a limited $\varnothing/h$ ratio allowed to recognize a degree of homogeneity higher compared to the other typological classes. This aspect could result by several factors, such as: the attribution of the ceramic shape to a limited number of function and/or the evidence of a model widely shared within the Fiorano culture, where jugs are one of the most distinctive shapes of this material culture [39]. Similar case for truncate cone-shaped vessels, typical of Vhò group, where the wide volumetric range could be the outcome of a

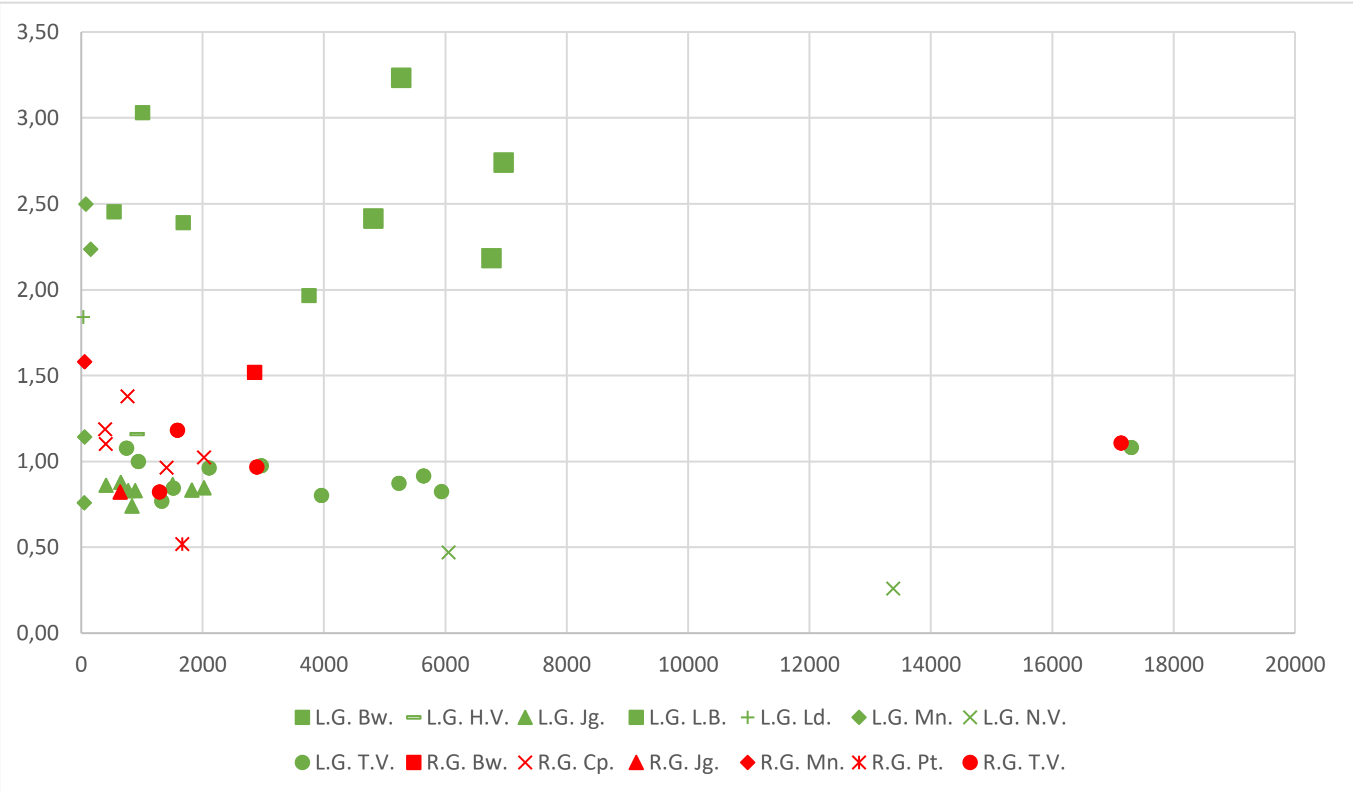

Figure 8. Scatter plot between volumetric capacity (X axis) and diameter/height ratio (Y axis). Lugo di Grezzana (L.G. = green), Riparo Gaban (R.G. = red); Legend: Bw. = Bowl; Cp. = Cup; H. V. = Handle Vessel; Jg. = Jug; L.B. = Large Bowl; Mn. = Miniaturistic; N.V. = Necked Vessel; Pt. = Pot; T.V. = Truncate cone-shaped vessel.

plurality of technological aspects. For example, aspects like an unrestricted orifice, thick walls and bases, in particular in large samples for increase stability, could be assumed as dry storage vessels [20], but an evaluation of their functionality is not possible yet.

Regarding the functions of each ceramic class, although the volumetric capacity depends upon its shape and size, it was not possible to formulate a direct relationship with the function. As has been seen in Rice [20], pots are multifunctional with primary or secondary uses before being abandoned. In other words, the relation between use and capacity of a vessel depends on several considerations like the amount and kind of contents (liquid or solid), the duration of storage, the number of uses, microenvironmental factors or other necessities [40], [41]. To understand this complexity, volumetric and typological aspects must be related to other technological criteria like petrographic analysis, surface treatment processes (smoothing, polishing, slip) [42], use-wear and organic residues [43]-[45].

Ceramic paste and manufacturing analysis are under study and will be able to provide new interpretative ideas about the functionality of each typological class.

6. CONCLUSION

This study aimed to provide new data about the estimation of the volumetric capacity of ceramic vessels from the Neolithic sites of Lugo di Grezzana and Riparo Gaban, with the aid of 3D graphic software. The automatic calculation, based on a reconstruction of the vessel through Blender®, represents an efficient method for the estimation of the volumetric capacity since: allow to work directly on the bibliography available, the volumetric calculation takes place in just few steps with very reliable results and sufficiently valid to be applied to an archaeological study.

The results show a different distribution of the ceramic dataset that could depend on different reasons like a poor conservation of some typological classes, that would not allow to estimate the volume or due to a different connotation of the two sites.

About the distribution of each typological class for the most part of them it was possible to highlight a specific distribution of the results, according to four trends, each of them could be conditioned by functional uses and/or cultural models.

To date, numerous questions have therefore emerged and remain unresolved, especially regarding jugs and truncate cone-shaped vessels. Could a limited volumetric range and $\varnothing/h$ ratio of the jugs be an evidence of a restricted number of functions? At the same, its homogeneity is shared within other sites belonging to the Fiorano culture? How far is it diversified compared to other contemporary cultures of the northern Italy? Conversely in the case of truncate cone-shaped vessels, could a wide volumetric range and limited $\varnothing/h$ ratio represent a plurality of technological aspects compared to other typological class?

In general terms, the study of vessel capacity is one of the parameters necessary for the functional understanding of the artifacts. However, only through a systematic application of this method to other contemporary sites and the evaluation of further investigation parameters (currently in progress), it will be possible to obtain more information about the functionality of ceramic vessels.

ACKNOWLEDGEMENT

The research project is conducted by the research laboratory LaBAAF (Laboratorio Bagolini Archeologia Archeometria Fotografia) belongs to CeASUm (Centro di Alti Studi Umanistici) of the University of Trento. The project has Prof.ssa Annaluisa Pedrotti as scientific manager and Paolo Chistè as technical director of TeFaLab (Laboratorio di Tecniche Fotografiche Avanzate, unit of LaBAAF). All the authors equally contributed to research and writing.

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