Abhandlung

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Salt, clay, and society: Towards a reconstruction of salt-making *chaînes opératoires* in the Bronze and Early Iron Age in the Kraków–Wieliczka salt-bearing region

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Zusammenfassung: Die Fortschritte bei der Feldforschung und den Untersuchungen archäologischer Fundstellen in Südpolen (Kleinpolen) sowie die experimentellen Aktivitäten im Zusammenhang mit der bronzezeitlichen und früheisenzeitlichen Salzgewinnung in den letzten zwei Jahrzehnten haben die Voraussetzungen zur Rekonstruktion der Chaîne opératoire dieses Zweigs der prähistorischen Herstellung geschaffen. Die Verwendung keramischer Gefäße für die Verdampfung der Sole und die Trocknung und Dosierung des Salzes macht deutlich, dass wir es hier mit zwei Arbeitsabläufen (Keramik- und Salzproduktion) zu tun haben, die in einem bestimmten Stadium ineinander greifen – von der Beschaffung der Rohstoffe (Ton und Sole) über den Vertrieb des transportfähigen Produkts bis hin zur Entsorgung der Einwegbehälter. Auf der Grundlage des gesamten verfügbaren Materials aus West-Małopolska, insbesondere aber auf der Grundlage mehrerer ausgegrabener Siedlungen (Podłęże 17, Brzezie 17 und Kraków-Bieżanów 11) haben wir eine vielschichtige Studie über die Merkmale der Materialien durchgeführt, die mit jeder dieser Phasen verbunden sind, einschließlich ihrer räumlichen Lage. Dadurch konnte eine gewisse Vielfalt an Braustätten festgestellt werden. Eine umfassende Betrachtung der Quellenbasis hat auch eine eher begrenzte Bandbreite sowohl des Grades der handwerklichen Spezialisierung der Brauer als auch des Umfangs des Einflusses des Zentrums ergeben. Dennoch erlangte das Zentrum in einigen Perioden, wie z.B. zu Beginn der Urnenfelderkulturen, überregionale Bedeutung, was u. a. durch Belege für standardisierte Gewichte der Fertigprodukte belegt wird.

Schlüsselworte: Salz, Brauerei, Soleverdampfung, Briquetage, Arbeitsabläufe, handwerkliche Spezialisierung, Bronzezeit, frühe Eisenzeit, Südpolen, Kleinpolen

Abstract: The progress of field research and studies of archaeological sites from southern Poland (Małopolska) and experimental activities related to salt-making in the Bronze Age and Early Iron Age in the last two decades have created conditions for attempting to recreate the *chaîne opératoire* of this branch of prehistoric production. The use of ceramic containers for evaporating brine and drying and portioning salt means that we are dealing with two operational sequences (production of ceramics and salt) intertwined at some stage – from obtaining raw materials (clay and brine) to the distribution of transportable product and discarding of disposable containers. We conducted multi-aspect studies on the characteristics of materials related to each stage, including their spatial location, based on all available material from western Małopolska, in particular several large-scale benchmark sites (Podłęże 17, Brzezie 17 and Kraków-Bieżanów 11). This allowed us to identify certain differences in production sites. A comprehensive review of the source database also allowed us to establish a rather limited scope of both the degree of craft specialisation of the brewers and the scale of the centre's influence. Nevertheless, in some periods, as in the beginning of the Urnfield period, this centre gained supra-regional importance, as evidenced by, among others, certificates of weight standardization of finished products.

Keywords: salt, salt-making, brine evaporation, briquetage, *chaînes opératoires*, craft specialisation, Bronze Age, Early Iron Age, S Poland, Małopolska

Abstrakt: Postęp badań terenowych i opracowań stanowisk archeologicznych z południowej Polski (Małopolski) oraz działań eksperymentalnych związanych z warzelnictwem soli epoki brązu i wczesnej epoki żelaza w ostatnich dwóch

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dekadach stworzył warunki do odtwarzania łańcucha operacyjnego tej gałęzi prehistorycznej wytwórczości. Wykorzystanie pojemników ceramicznych do odparowywania solanki oraz suszenia i porcjowania soli, sprawia, że mamy tu do czynienia z dwoma przeplatającymi się na pewnym etapie sekwencjami operacyjnymi (produkcją ceramiki i soli) – od pozyskania surowców (gliny i solanki) po dystrybucję transportowalnego produktu i utylizację jednorazowych pojemników. Wieloaspektowe studia nad charakterystyką materiałów związanych z każdym z tych etapów, łącznie z ich przestrzenną lokalizacją, przeprowadziliśmy w oparciu o cały dostępny materiał z zachodniej Małopolski, lecz w szczególności na bazie kilku przebadanych na szeroką skalę wykopaliskowo osad (Podłęże 17, Brzezie 17 i Kraków-Bieżanów 11). Pozwoliło to zidentyfikować pewne zróżnicowanie stanowisk warzelniczych. Całościowy ogląd bazy źródłowej pozwolił też na stwierdzenie dość ograniczonego zakresu zarówno stopnia specjalizacji rzemieślniczej warzelników, jak i skali oddziaływania ośrodka. Mimo to, w niektórych okresach, jak w początkach kultur pól popielnicowych, ośrodek zyskiwał ponadregionalne znaczenie, o czym świadczą m.in. świadectwa standaryzacji wagowej gotowych produktów.

Słowa kluczowe: sól, warzelnictwo, odparowywanie solanki, brykietaż, sekwencje operacyjne, specjalizacja rzemiosła, epoka brązu, wczesna epoka żelaza, Polska południowa, Małopolska

1 Introduction

Extracting salt, a mineral necessary for the human body and a valuable, unevenly distributed natural resource, is one of the areas of activity of prehistoric communities that can be successfully studied in archaeology using the method of operational sequences (*chaînes opératoires*)[1]. As noted earlier on many occasions[2], when producing salt from brines with the help of vessels used to concentrate it, two technological processes intertwine: (1) obtaining and evaporating brine and packaging salt, and (2) the production and use of ceramics for this purpose. In theory, obtaining the saline water and its initial concentration could take place independently of the production of the vessels used for its evaporation. There is, however, a strong spatial connection between these two branches of production, as briquetage vessels, for economic reasons, had to be manufactured near the presence of salt springs. After the completion of the entire crystallisation process, the two main segments of production were separated again: on the one hand, it was salt, distributed in loose or compact form as transportable salt artefacts (so-called 'salt cakes'), on the other, the remains of single-use vessels (briquetage) left on-site in the form of ceramic debris. The literature review shows that in each region of the world with this type of salt production technique documented, one deals with a slightly different detailed course of both processes, the use of different materials (e. g. to form moulds) or slightly different ceramic forms[3]. With regard to the vicinity of Kraków in western Małopolska (Lesser Poland; southern Poland), the growing quantity of research and experiments over recent years has enabled this article to present an almost complete, regional-scale reconstruction of operational sequences related to the production of salt and the production of ceramics for this purpose, based on archaeological sources obtained from 'salt-making' sites from the 2nd and 1st millennium BC.

Despite the rich literature on the subject, the problem of the organisation of salt production in Central Europe in the Bronze Age and the Early Iron Age has still not been satisfactorily described. In western Małopolska, some of the oldest traces of organised salt-making using a standardised toolkit have been recorded and date back to the Middle Neolithic[4]. Until recently, however, the discontinuity in the archaeological record of salt production was noticeable in this area, including in such fundamental issues as the identification of traces of salt-making devices and ceramic vessels (briquetage) used in the concentration of brine. Particularly interesting was the lack of sources of this kind concerning the Early and Middle Bronze Age[5]. However, recent years have brought a radical change in this matter (Fig. 1). Source materials, obtained during wide-ranging rescue archaeological excavations conducted in the vicinity of Kraków in connection with the construction of the A4 motorway, made it possible to almost completely fill this gap[6]. These are sites explored on a wide scale (usually with an exposed area of more than 1 ha), where hundreds of thousands (up to several million) fragments of briquetage pottery were discovered. The enormous amount of new sources on prehistoric salt-making obtained this way was dated to the Bronze Age and Early Iron Age (1300–450 BC) and was included in the scope of a broader and more com-

1 E. g. Roux 2016.

2 Cf. Harding 2013, 112–116, with older references therein.

3 E. g.: Gouletquer/Weller 2015; Harding 2021; Weller/Ard 2024.

4 Jodłowski 1976; 1984; Saile 2012; Harding 2013, 49; Przybyła 2015; Zastawny/Grabowska 2017.

5 Kadrow/Włodarczak 2003; Saile 2000, fig. 3; 2012, fig. 1.

6 Kadrow 2003; Przybyła 2015; Przybyła M. M. 2017; Matoga 2017; Mazur/Dzięgielewski 2021.

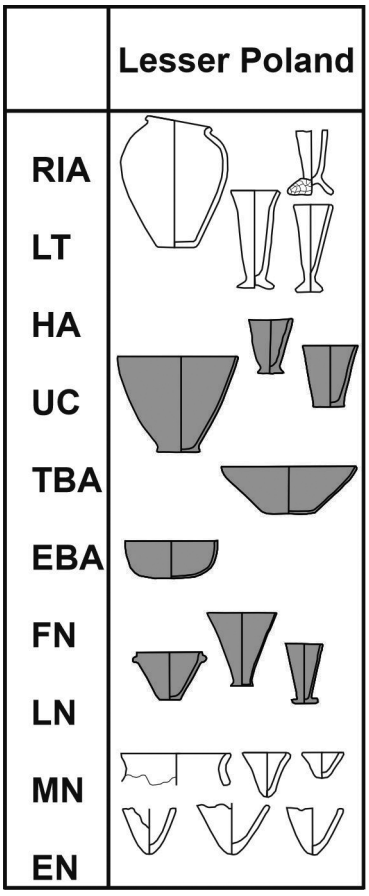

Fig. 1: Progress in recognising the continuity of prehistoric salt exploitation in Małopolska (Lesser Poland) over the last 20 years within the respective diagram by Th. Saile (2000, fig. 3) showing the development of salt-making ware in Europe (new data marked grey).

plementary study carried out at the Institute of Archaeology of the Jagiellonian University under the title: 'Inheritance, social network or local adaptation? Bronze and Early Iron Age societies in western Małopolska'[7]. While running this research project that addresses the question of interplay of cultural transmission patterns within prehistoric societies, salt production was also investigated, understood as a technological and social process of obtaining and distributing the resource from salt springs available only in a limited area (the problem of unevenly distributed resources).

The aim of this article is to present the detailed results obtained during the above-mentioned project and several smaller projects carried out in recent years, consisting in detailed analyses of archaeological remains from the key sites studied by the authors of this article (Kraków-Bieżanów 11, Kraków district; Brzezie 17, Wieliczka district; Podłęże 17, Wieliczka district; Biskupice 1, Wieliczka district; for the locations of the more frequently mentioned sites see Fig. 27). The article consists of several parts: The analysis of the availability of the raw material is accompanied by an attempt to reproduce in detail the broadly understood technological processes related to salt-making, including the identification of the assortment of ceramic tools used in the process of brine evaporation and salt distribution. Afterwards, an attempt was made to understand the role of this raw material in the economic and social life of late prehistory societies in western Małopolska. Recognition of the scale of the phenomenon in this region may also help in understanding the role of other Bronze Age–Early Iron Age salt production centres in Central Europe, including challenging the opinion on the 'monopoly position' of the Hallstatt salt mine[8].

2 Environmental conditions

The occurrence of saline sources in western Małopolska is related to the geological structure of the northern pre-Carpathian area, the so-called Carpathian Foredeep area, where shallow evaporates (saline clays, gypsum, salts) occur under the Quaternary sediments of alluvial-colluvial nature and Miocene layers. The geological cover of this region is formed by the sediments of the Miocene Sea that are not very resistant to erosion (clay-sand layers of Chodenice and Bogucice sands), together with the Late Badenian (13.5 Mya) series of evaporates in the form of salt, saline clays, gypsum and anhydrites. Chloride facies, including halite (crystalline NaCl, the rock salt), were deposited during the Middle Miocene mainly in the deepest places (sub-basins) of the evaporation basin, along the lines of the uplifting Carpathians. These sediments were then raised to the surface as a result of uplift and overthrusting of the rock mass (Fig. 2A; 3)[9]. This process later enabled the leaching of salt deposits by groundwater and the formation of salt springs in land depressions[10]. Within the Chodenice and Grabowiec layers, locally available just below the surface, there are also good-quality clays that can be used in ceramic production[11]. In the greater part of the western section of the salt-bearing area, however, mainly Miocene sandy sediments (Bogucice sands), with a low degree of natural salinity and without good clay deposits, are available on the surface[12]. Quater-

7 Przybyła *et al.* 2024.

8 cf. Reschreiter *et al.* 2009, 309.

9 Wiewiórka 1988; Krzywiec 1997; Bukowski 2003, 274–276, fig. 1–3; Oszczypko 2006; Cyran 2008, 16–18.

10 Bukowski 2003, 276.

11 Ibid. 276; Rauba-Bukowska 2014, 473–474.

12 Bukowski 2003, 276, 280.

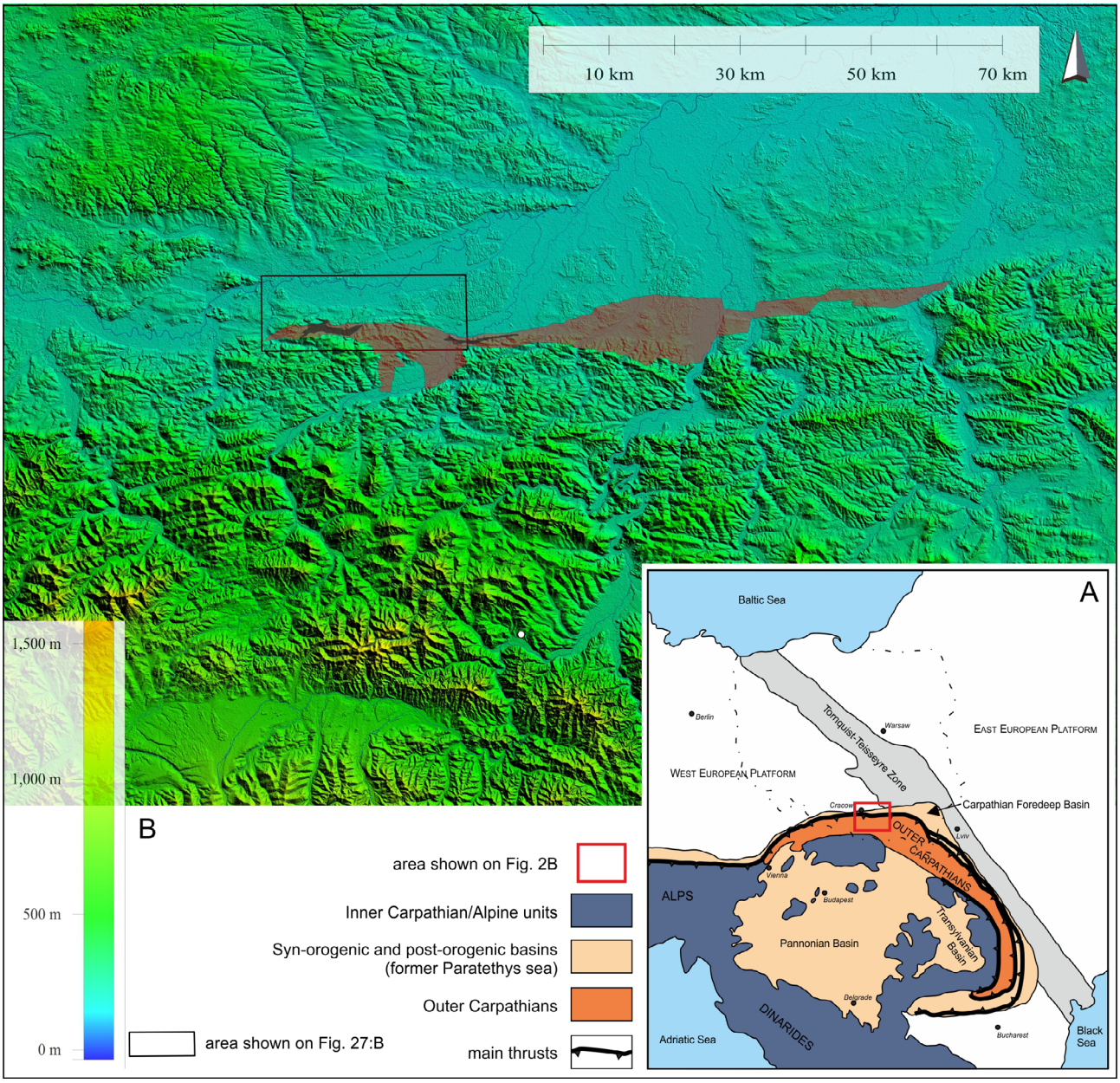

Fig. 2: A – location of the research area within the general geological sketch of Central and Eastern Europe, showing the relationship between salt-bearing formations in the Carpathian Foredeep and the thrusting of the Carpathians during the Alpine orogeny (according to Krzywiec 1997, simplified); B – digital elevation model of western Małopolska showing the occurrence of Miocene autochthonous (undisturbed) evaporites with rock salt (halite) (dark grey; according to Wiewiórka 1988; after Cyran 2008, modified) and allochthonous evaporites (sediments of the Zgłobice Unit, folded as a result of the Carpathians thrusting) (light red; after Cyran 2008, modified).

nary sediments lying on these layers are mainly Pleistocene alluvial-periglacial sands (in the western part) and loess from the Vistula glaciation period (Vistulian), mainly from the younger Pleniglacial[13]. Nevertheless, in the depressions in the entire salt zone, it was (and is) possible for groundwater to reach the sediments of much older evaporates (mainly in the area of rock salt occurrence in Wieliczka and Bochnia) and to wash them out to surface waters. Archaeological and historical records of water salinity are certified especially for watercourses such as Malinówka (Kraków-Barycz, Kraków-Bieżanów), Serafa (Wieliczka, Kraków-Bieżanów, Kokotów), Bogusława (Biskupice, Przebieczany, Zakrzów), and also Tusznica (Brzezie) or Babica (Bochnia). At present,

13 Ibid. 276.

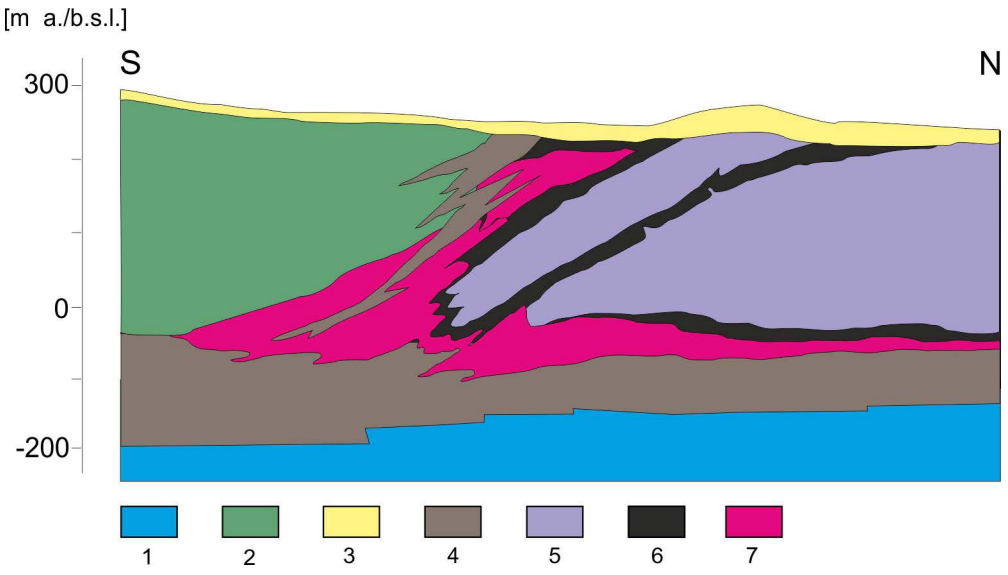

Fig. 3: Geological structure in the vicinity of the Barycz salt deposit, Wieliczka district: 1 – Cretaceous, 2 – Carpathian flysch, 3 – Bogucice sands (Miocene) and Quaternary formations, 4 – Skawina strata (evaporite floor formations), 5 – Chodenice strata, 6 – sulphate facies, 7 – evaporites (salts). Based on: Wiewiórka 1988; Bukowski 2003; Cyran 2008.

Tab. 1: Hydrochemical parameters (selected elements) of stream water and groundwater (mg/l) in the vicinity of two sites with traces of the Bronze Age salt production (sampling 2018), determined using the ICP technique (Inductively Coupled Plasma Optical Emission Spectroscopy) on the ICP-OES Thermo iCAP 6500 DUO spectrometer at the laboratory of the University of Agriculture in Kraków (analysed by Piotr Gruba).

	Ca	K	Mg	Mn	Na	Fe	Zn	Ni	Pb	Cu
Biskupice 1 (Bogusława creek)	88,34	2,84	8,09	0,0220	16,92	0,025	0,0051	4,510	0,709	0,000
Brzezie 17 (modern well)	138,70	2,86	20,52	0,0046	32,21	0,091	0,0070	4,045	0,000	1,758

as a result of anthropogenically induced changes (especially lowering the groundwater level), among others, the salt springs in most of the described area have almost completely vanished. It seems likely that fluctuations in groundwater levels throughout the Holocene may have led to the periodic appearance and disappearance of surface-accessible waters with adequate salinity in specific places. Thus, in the identification of salt springs in different epochs, it may be helpful to track the presence of salt-making pottery (briquetage) in archaeological sites, as well as the presence of macroremains and pollen of halophyte vegetation. Thanks to the analyses of the chemical composition of water in the area of archaeological sites with records of Bronze Age salt-making, we know both cases of low modern salinity of local pools and watercourses (e. g. in the area of Kraków-Bieżanów[14]) and salinity of streamwater (Bogusława river in Biskupice) and underground waters (well in Brzezie, site 17) (Table 1) higher or close to average in the Carpathian Foothills[15]. This state of affairs confirms the observation that the research of modern salinity alone cannot answer the question about the location of prehistoric salt-making sites. They must be supplemented with archaeological evidence.

3 Archaeological record of two *chaînes opératoires*

The two *chaînes opératoires* associated with making of salt in ceramic vessels – the pottery making and the salt making – can only be separated to a certain extent and at certain stages of production, i. e. in the initial and final stages (cf. Fig. 28). The 'ceramic' sequence, which will be presented here first (chapter 3.1), is to some extent independent of the main 'salt-making' sequence. When discuss-

14 Ibid. 279–280.

15 Cf. Żelazny/Siwek 2012, table 2.

ing the latter (chapter 3.2), the steps in the *chaîne opératoire* related to the use of ceramics will be discussed in the form of references to the first of the sequences.

3.1 Ceramic sequence

Material from Małopolska perfectly suits the general characteristics of single-use salt-making ceramics recently listed by Weller and Ard[16]. The vessels are open in shape, created with simple and quick forming methods, using local clays and numerous and heterogeneous tempers. Their external walls are unworked, decoration is limited to finger marks, and fragmentation is prominent. There are, however, local peculiarities which this chapter aims to describe.

3.1.1 Clay extraction

The production of briquetage vessels used in the brine evaporation process required easy access to large amounts of clay and – as it should be assumed – both of its stages, i. e. obtaining the raw material and preparing vessels, could not take place far from the salt production sites. Mineralogical and petrographical analyses of local clay resources carried out for selected sites with traces of salt production near Kraków proved that in environs of at least some of them there were deposits of clay useful for the production of ceramics (e. g. site 17 in Brzezie[17]). The direct archaeological proof that the production of ceramics was carried out in these sites was also the discovery of clay pits, the largest of which, from Brzezie, seems to be unquestionably related to the production of the briquetage. Although a large amount of ordinary kitchenware was discovered in the upper layers of this structure, the vast majority of remains deposited in its fill were crushed relics of salt-making vessels. This facility was located on the western edge of the settlement, not far from the place where the initial brine evaporation probably took place (Fig. 4). A similar situation was observed in the case of site Kraków-Bieżanów 11, where a clay pit partially filled with salt-making pottery debris was located in the southern part of the settlement. Although most of the area of this site was located on the sandy terrace of the nameless tributary of the Serafa (tributary of the Vistula River), its southern fringe was lying in the marshy floodplain zone, and this was the production area in which objects filled with briquetage debris were registered. However, no traces of clay extraction were confirmed at sites with salt-making ceramics occurring in smaller quantities, i. e. sites that did not provide traces of the full salt-making process, and probably only the stages of drying and salt packaging, or were even only inhabited by people associated with salt production (e. g. Podłęże 1; Podłęże 17; Kraków-Mogiła 62). In conclusion, it can be stated, mainly on the basis of the premises obtained in Brzezie 17 and Kraków-Bieżanów 11, that the extraction of clay for salt-making pottery was performed primarily on the basis of strictly local resources, most likely only at sites with a full salt production sequence (cf. Fig. 28).

3.1.2 Pottery making

The main obstacle in reconstructing scale of the prehistoric salt-making process is the difficulty involved in unambiguously identifying salt vessels. It must be assumed that for this process, apart from specialised briquetage-type forms, also (and sometimes exclusively) 'regular' kitchenware was used, i. e. vessels that did not differ morphologically or technologically from ordinary household pots. On the other hand, the very large fragmentation of the salt production ceramics makes it difficult to reconstruct the moulds. In order to develop a method allowing for reliably identifying salt-making vessels, in particular with regard to highly fragmented material, three independent studies were carried out within our project. The first and most important was an analysis of the quantity (criterion of 'mass use'), as well as the context and spatial relationships of each formal entity based on the general structure of archaeological material. It was assumed that the following are the typical features of salt-making ceramics: mass occurrence, formal and decorative homogeneity, and the use of opportunistic technics and means of production. On this basis, and on the basis of formal analogies known from the literature[18], four formal-functional groups of ceramics were selected (chapter 3.1.2.1), which were characterised in terms of technology mainly by macroscopic observation (chapter 3.1.2.2). Then, samples of the distinguished groups of ceramics were subjected to mineralogical and petrographic verification compared with 'ordinary' kitchenware (chapter 3.1.2.3[19]). The last stage was an attempt to distinguish chemical markers among the ceramics (both those recognised as salt-making and others) that could provide direct evidence of contact with brine (using the XRF technique). The results of the latter studies, which so far have not identified forms other than those dis-

16 Weller/Ard 2024, 2.
17 Rauba-Bukowska 2014.
18 E. g. Tencariu 2018.
19 See also Borowski 2020.

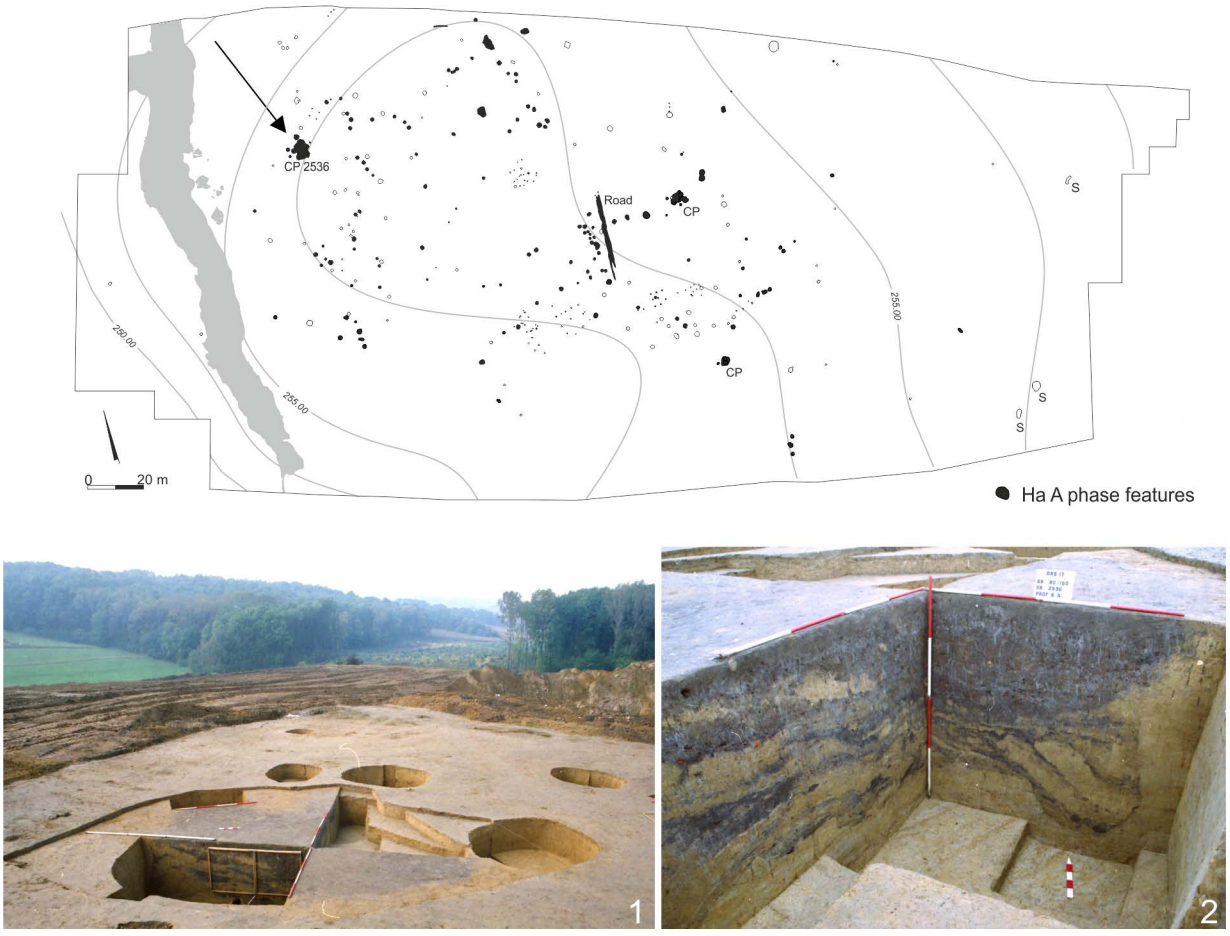

Fig. 4: Brzezie, site 17. Wieliczka District. Late Bronze Age open pit (feature 2536) for extraction of clay used in production of pottery, probably including the salt-making pottery. Location of the clay pit within the settlement dated to the Hallstatt A phase is marked in with a black arrow; CP stands for clay pit. Photo by A. Czekaj-Zastawny, A. Zastawny, drawing K. Dzięgielewski.

tinguished during macroscopic observations as briquetage, will be presented in a separate article.

3.1.2.1 Formal and functional division of pottery

We identified four main forms of pottery containers and objects of various functions in Bronze Age and Early Iron Age salt production in western Małopolska. The form of the containers shows a specific evolution over time (Fig. 5). In materials from the Early Bronze Age (EBA), associated with the late Mierzanowice culture (part of the Subcarpathian Epi-Corded Ware cultural circle[20]), only large, wide-mouth conical or hemispherical bowls were associated with salt production[21], referred to herein as Form 1a (Fig. 5). Their shape facilitated the initial evaporation of the brine, either naturally (in the sun) or with an additional heat source (fire). Most of them were provided with holes under the rim, which were probably used to hang the vessel over the fire, which was confirmed experimentally[22] (Fig. 6,1). Therefore, they were also used in the critical, high-temperature phase of brine evaporating. These vessels have been found so far only in a few sites in the area of the salt-bearing belt on the right bank of the Vistula (Kraków-Bieżanów, site 15, 18 and 34[23]; possibly also: Wieliczka, site 8[24]), in the unambiguous context of salt-making hearths. Surprisingly, they have been found in a quite large number at a single site on the left, loess bank of the Vistula River in Kraków-Pleszów (site IV/20)[25], which may testify to their production also outside the saline area and/or transporting the final product in vessels over short distances. In the Middle Bronze Age

20 See Włodarczak 2017.
21 Przybyła 2015, 173–176, fig. 5; 9; Włodarczak 2017, 72 fig. 16.
22 Przybyła 2015, 174–175.
23 Ibid. 174.
24 Fraś/Kolebuk 2021, 259 fig. 1,1.
25 Madej 1998.

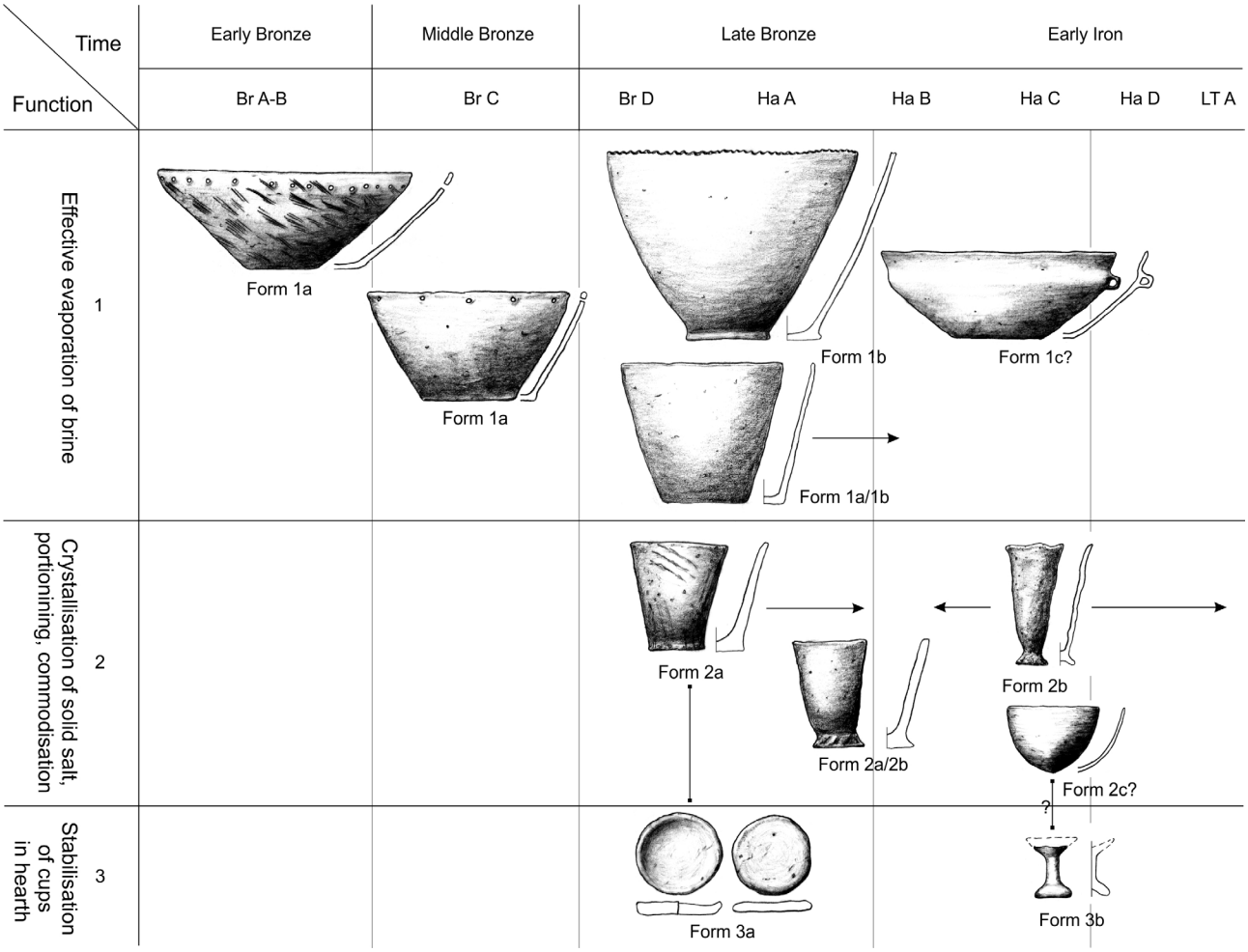

Fig. 5: Chronological and functional development of a set of ceramic vessels used in the salt brewing process in Małopolska in the Bronze Age and the Early Iron Age. Drawing K. Dzięgielewski.

(during the times of the Trzciniec culture[26]), only this form of vessel was still used near Kraków. Form 1a, a hemispherical briquetage bowl with holes under the edge, accounted for over 95 % of the movable inventory (almost 140,000 fragments) at the production site in Kraków-Bieżanów 15[27]. A less numerous series (in the proportion of approx. 52 % of the movable inventory) was provided by the nearby site in Zakrzów 1, District Wieliczka, where other ceramic forms of the Trzciniec culture also occurred[28]. Also in this time horizon, as in the Early Bronze Age, such bowls were revealed less frequently in sites located on the left, loess bank of the Vistula River, where the agricultural settlement of the Trzciniec culture was concentrated[29]. In the salt production sites, these vessels usually had a very fragmented state of preservation and their identification often takes place only thanks to the characteristic perforations under the rim (Fig. 5). Using these containers made it possible to obtain a finished product (evaporated salt) but did not allow for direct production of standardised distribution units (salt cakes): the salt was simply scraped off the walls.

At the beginning of the Late Bronze Age (Br D–Ha B1; 1300–1000 BC), within the settlements of the early Lusatian culture (representing the Urnfield cultural circle) or of mixed traits of the Lusatian culture and the Transcarpathian Belegiš II culture[30], a far more diverse set of salt-making pottery appeared. While the large evaporation vessels were still in use (now also in form of higher, conical beakers referred here as Form 1b: Fig. 5; 7,1), the final drying phase of the salty molasses would now take place in smaller contain-

26 See Górski 2017.

27 Przybyła 2010; 2015, 176–178 figs. 6; 9.

28 Przybyła 2015, 178.

29 Górski 2007; 2023.

30 Cf. Przybyła M. S. 2017, 236–239; Dzięgielewski 2024.

Fig. 6: Salt brewing thermal experiments in Małopolska: 1 – brine evaporation in a hanging bowl (Form 1a), 2 – subsequent stages of evaporation in bowls (Form 1a) set in three-part hearth, 3, 4 – salt cakes formation in cups Form 2b. Experiments designed by M. M. Przybyła and J. Górski (Archaeological Museum in Kraków, photo by K. Dzięgielewski) (1–2), and by J. Fraś and S. Pawlikowski (Cracow Saltworks Museum in Wieliczka, photo by J. Fraś) (3–4).

ers (Form 2a; Fig. 5). It is these vessels: squat, conical cups of more or less standardised size, that are most often referred to in the literature on the salt-making of the Kraków region as briquetage. (In fact, this name must also cover the specimens of Form 1, which are besides often indistinguishable in fragmented material from the conical cups).

Smaller cups represent not only a new shape and size, but more importantly a newly introduced stage in the salt-making process: the final drying of the salty molasses combined with forming of transportable portion of solid salt – a salt cake. Therefore, such forms have to be distinguished as a separate functional group, here referred as Form 2. What differs them from large bowls and beakers (Form 1) is a much stronger degree of secondary burning on the surfaces, suggesting that these vessels used to be placed close to fire or directly in fire (on the embers or on special ceramic or stone supports). Discoidal ceramic pads or stands made especially for this purpose (to ensure the stability of the cup in the hearth) are distinguished here as another functional group – Form 3 (Fig. 5). The pads show the strongest traces of secondary burning among all forms, often reaching a purple or white colouration of the surface (Fig. 15); the same is true for bottom parts of Form 2a cups (Figs. 14: 2, 4; 17). The small differentiation in the size and volume of the Form 2a cups leads to the conclusion that thanks to their use relatively standardised salt cakes were obtained. The detailed analyses of materials from some of the studied sites, in particular Kraków-Bieżanów 11 (Fig. 7), Biskupice 1 (Fig. 8) and Brzezie 17 (Fig. 9), suggest that Form 2a accounts for most of the production ceramic-debris recorded (Fig. 5). The significant volumes of debris from this type of briquetage are influenced by the fact that they were quite massive vessels, with wall thicknesses often exceeding 1 cm in the lower part, approx. 14–25 cm high and base diam-

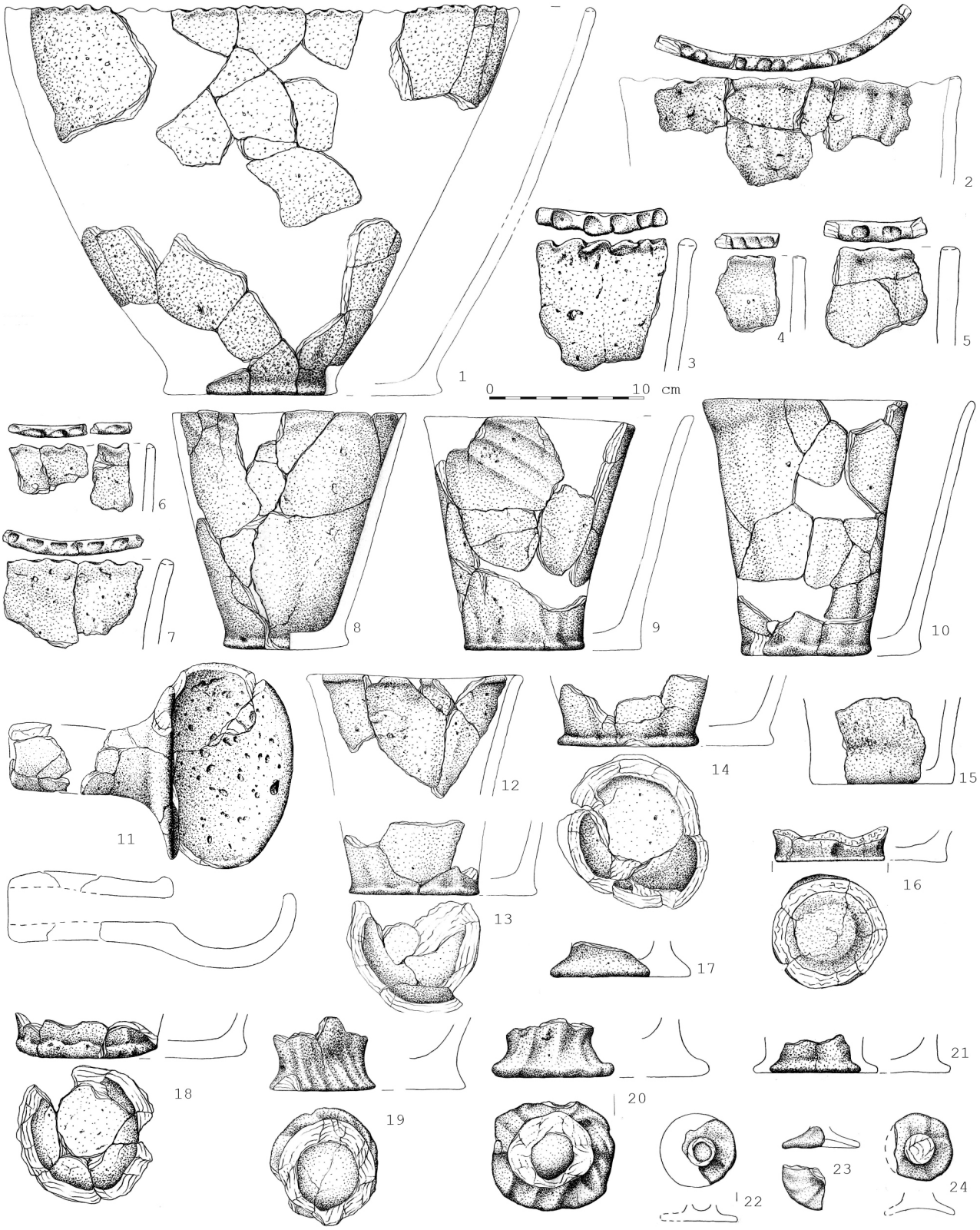

Fig. 7: Kraków-Bieżanów, site 11, remains of Late Bronze Age salt-making ceramics (briquetage): 1–5 – Form 1b, 6–7 – Form 1a/1b; 8–10, 12–18 – Form 2a; 11 – a ladle; 19–21 – Form 2a/2b; 22–24 – Form 2b. According to Mazur 2012.

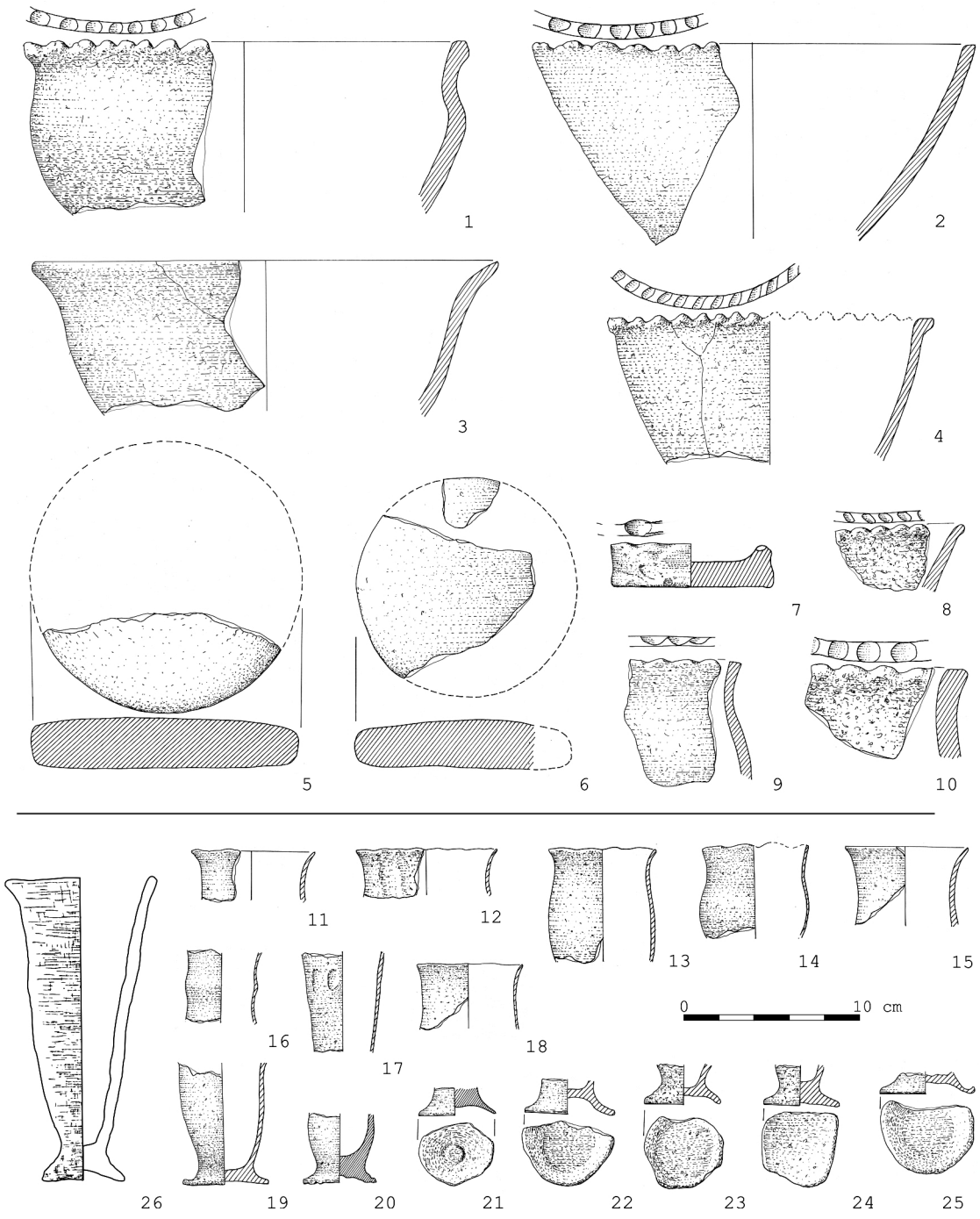

Fig. 8: Biskupice, site 1, remains of Late Bronze Age (1–10) and Early Iron Age (11–26) salt-making ceramics (briquetage): 1–4,7 – Form 2a, 5–6 – Form 3a; 8–10 – Form 1b?; 11–26 – Form 2b. Drawing by U. Bąk.

eters between 7 and 9 cm[31]. The use of the mentioned ceramic pads (Form 3a) (Fig. 5; 8,5–6; 9,27–30) was so far attested only in combination with Form 2a cups. Their diameter (usually 8–10 cm in Brzezie) slightly exceeds the dimensions of the cup bases – an additional indication of their functional relationship. However, they were found on a smaller number of sites than the cups themselves, which may be due to the state of research (so far: Brzezie 17, Biskupice 1, Kraków-Bieżanów 11 and Wieliczka 104) (Fig. 27)[32]. It cannot be ruled out that at other sites from the same period, small stone pads were

31 Cf. Fraś/Kolebuk 2021, 264.

32 Fraś/Kolebuk 2021, fig. 3,10–12; 5,13–16.

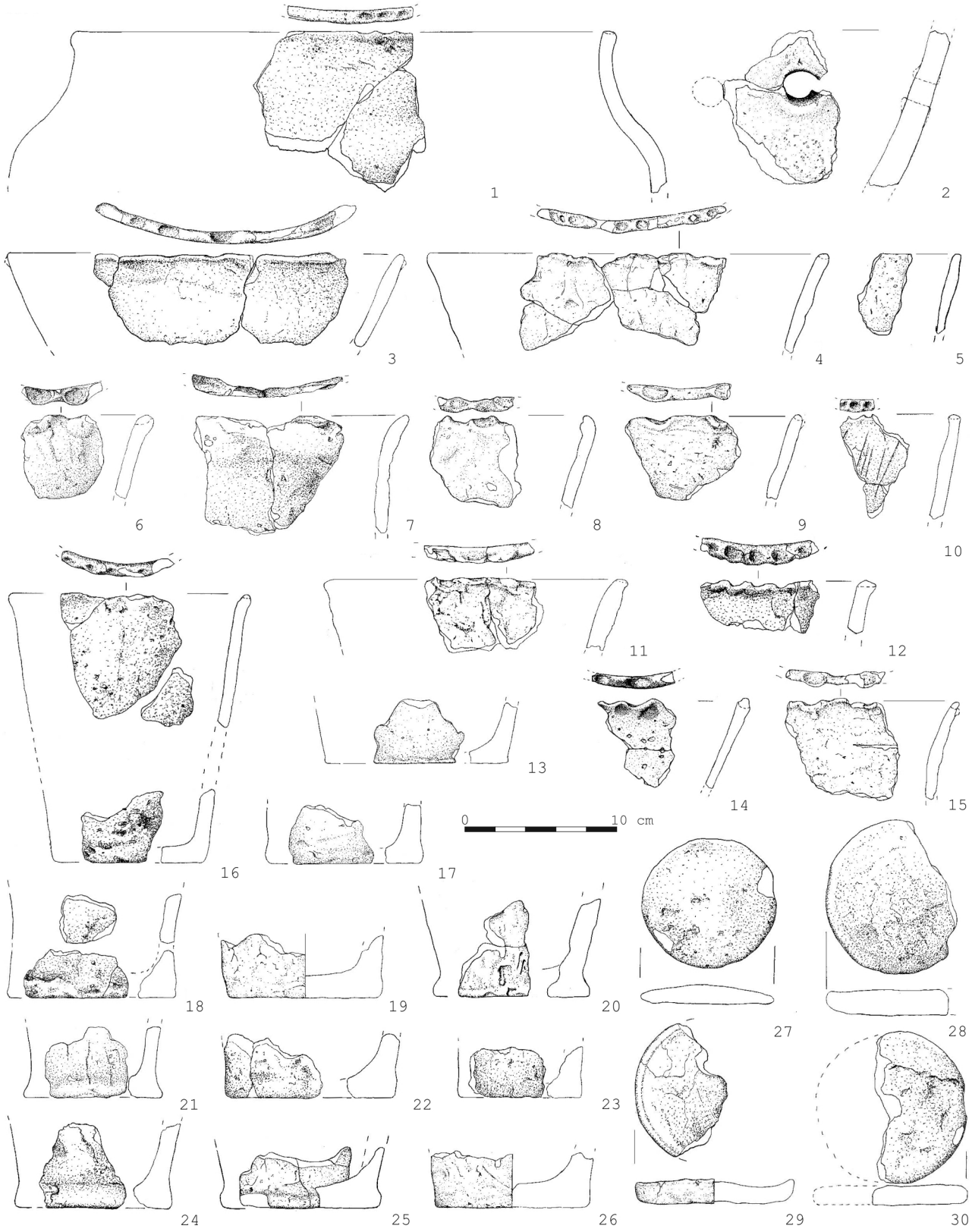

Fig. 9: Brzezie, site 17, remains of Late Bronze Age salt-making ceramics (briquetage): 1–11 – Form 1b, 12–26 – Form 2a; 27–30 – Form 3a. According to K. Dzięgielewski 2012b

used in this role (e. g. in Kraków-Bieżanów 11, a dozen or so flat round stones were registered – some of them severely burned out – which also could have fulfilled such a function).

The last, younger development form of the briquetage cup is a younger functional counterpart of Form 2a from the turn of the Bronze Age and Iron Age. Form 2b cups are more thin-walled, slim, and goblet-shaped (Fig. 5). It is this form that was first identified as related to the production of salt in Małopolska and was considered the only type of this kind for many years[33]. Compared to the older Form 2a, it is more slender and has a distinct stand separation (a foot). The thickness of the walls, even in the bottom part, rarely exceeds 0.5 cm, the height varies from 5 to 17 cm, and the diameter of the foot is mainly between 3 and 8 cm. Layers of ceramic debris at sites with Form 2b cups do not have such large volumes as at sites with Form 2a, precisely because of their thinner walls, which also affects the overall possibility of their preservation in the archaeological record. It cannot be ruled out that the second factor contributing to the lower volume of waste was the removal of the upper part of the cup (without the foot) from the production space together with the salt cakes inside (see chapter 4.1). This may be evidenced by the deposits consisting almost exclusively of feet of Form 2b vessels (Fig. 10)[34].

These cups are chronologically younger than the Form 2a conical cups and occur mainly in sites (or their phases) dating to the end of the Bronze Age, Ha B2–3 (950–800 BC), and the Early Iron Age, Ha C–D (800–500 BC). As suggested by A. Matoga[35], a more detailed chronological division of Form 2b is possible. According to this author, the older ones, related to the end of the Bronze Age and the beginning of the Iron Age, were made using a two-piece technique (inserting a conical body into a foot in form of circular disc) (Fig. 19,2). This is confirmed by the inventory of pit 30 in Wieliczka, site 112[36], containing such a variety of 2b cups together with vessels representing the local Dunajec pottery style from the turn of the Bronze and Early Iron Age[37]. The younger variety of 2b cups, developed in the Early Iron Age, are thought to have been formed using one-piece technique (pinching the foot from one piece of clay and gradually building up the body on it) (Fig. 16,2). Among the latter, thin-walled forms (Fig. 16,4) and forms on a massive foot (Fig. 16,5) are discernible, which according to Matoga, marks another evolutionary development. We will refer to these suggestions later in the text. At this point, it is worth noting that during the Late Bronze Age, with the replacement of Form 2a with Form 2b, there was apparently a change in the metric (weight) standard for the portion of salt – the Form 2b cups were able to contain a significantly smaller, even several times smaller, volume of this mineral (cf. chapter 3.2.4). The intermediate forms (2a/2b: Fig. 5; 7,19–21) discernible at some sites (Biskupice 1, Brzezie 17, Kraków-Bieżanów 11, Kraków-Bieżanów 27) – still quite massive, but with a strongly separated foot – document a gradual evolution from Form 2a into Form 2b. As for the end of the Bronze Age (Ha B2–3), what draws attention is the lack of Form 1 vessels, i. e. wide-mouth bowls or beakers known from the earlier stages of the Bronze Age and the beginning of the Late Bronze Age (Ha A–B1). It is therefore highly probable that for the initial stages of evaporation, ordinary kitchen containers were used at that time, mainly carinated, wide-mouth bowls, usually not identifiable as briquetage in mass ceramic material (Fig. 5: Form 1c?). This is suggested by the high frequency of this type of bowls at salt-making sites such as Kraków-Bieżanów 27 and Kraków-Rżąka 1[38].

Probably at the beginning of the Iron Age (Ha C), in this familiar ceramic repertoire based on preliminary brine evaporation in Forms 1c and final drying in Forms 2b, there was also room for experimenting with other forms, as evidenced by the discoveries on site 1 in Podłęże[39], that had produced several ceramic column pedestals, well known, for example, from the Early Iron Age salt production centres around Halle (Saale) in eastern Germany[40] (Fig. 5: Form 3b). It is unclear what portioning containers would accompany them, although the inventories of some household pits from the very site show the presence of small, pointed forms (Fig. 5: Form 2c?), unknown from other contemporary settlements in the region. In any case, these experiments did not result in the spread of the pedestals, since in the younger sediments, Ha D (e. g. in Podłęże 17), only Form 2b cups are again recorded, similarly as in the settlements of Ha B2–3. It remains to be speculated whether salt-making with the use of Forms 1c + 2b continued near Kraków at the very end of the cultural cycle of the Bronze Age and the Early Iron Age, in the times of the Pomeranian culture, i. e. at the beginning of the La Tène Period (LT A–B; V–IV century BC), before the arrival of the Celts[41]. From settlements of that age (Podłęże 17), only single specimens of Form 2b cups are known[42],

33 Gedl 1968; Jodłowski 1976; Saile 2000.
34 Fraś/Kolebuk 2021, fig. 9–10.
35 Matoga 2017, 148–150 fig. 3.
36 Fraś/Kolebuk 2021, fig. 8.
37 See Dzięgielewski 2024.
38 Pieróg 2003.
39 Rydzewski 1989.
40 Matthias 1961.
41 Cf. Dzięgielewski 2015; 2016.
42 Dzięgielewski 2015, 88 fig. 8,v-y.

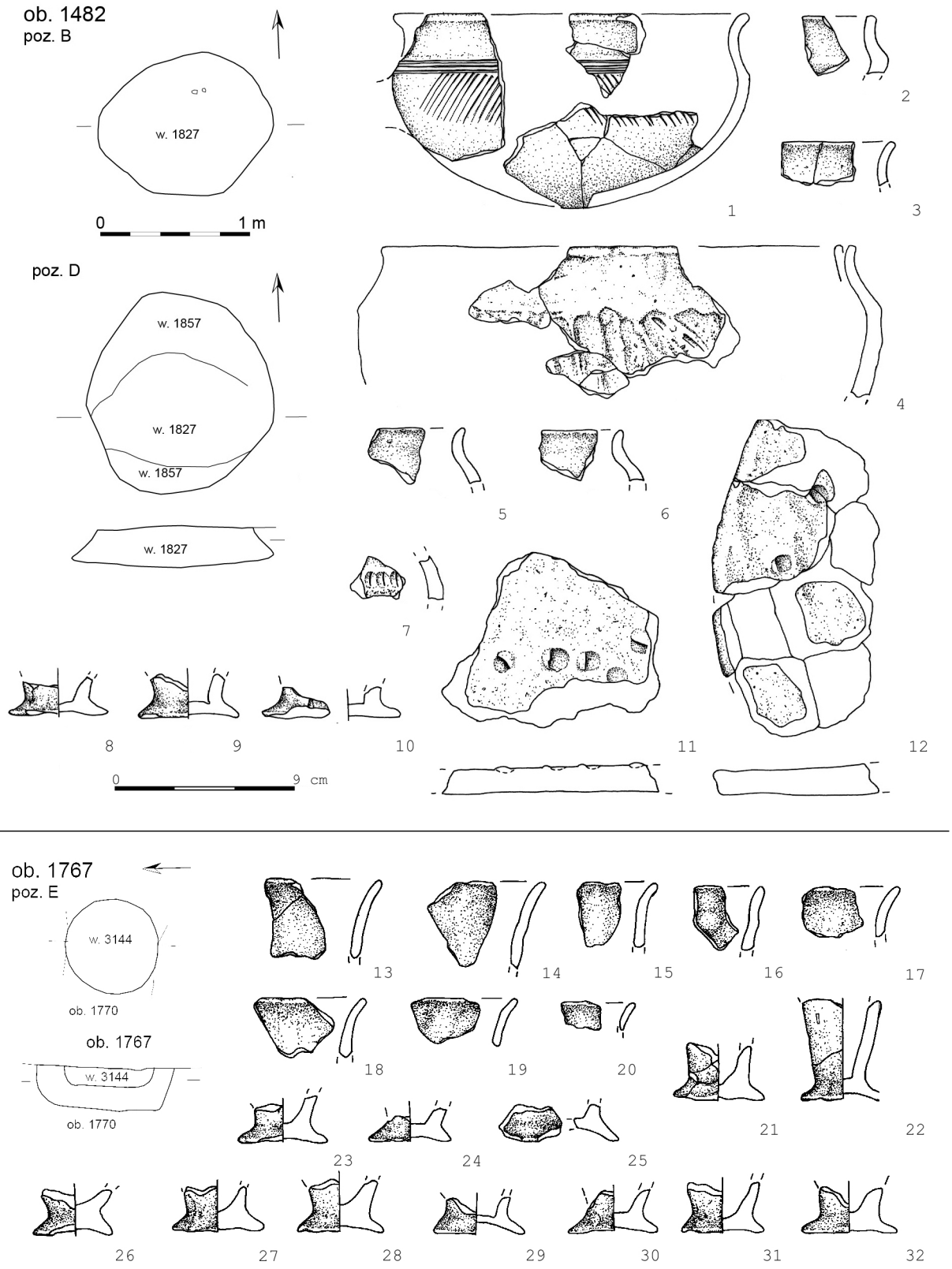

Fig. 10: Podłęże, site 17, examples of Early Iron Age inventories of settlement pits with salt-making ceramics (briquetage): 8–10, 13–32 – Form 2b. According to K. Dzięgielewski 2012a.

Tab. 2: The quantity of ceramic series from the vicinity of Kraków subjected to macroscopic analysis of production technology.

Site	Total number of ceramic units (c. u.)	Total number of briquetage c. u.	Number briquetage c. u. with full technological characteristics	Forms of briquetage	Chronology	Literature (U – unpublished reports)
Kraków-Bieżanów 11	648,323*	55,272**	1,901	1, 2a, 2b	Ha A–Ha B	Mazur 2012 (U)
Brzezie 17	ca 26,000	ca 18,000	2,789	1, 2a, 3	Ha A	Dzięgielewski 2012b (U)
Kraków-Bieżanów 27/ Kraków-Rżąka 1	37,672	23,263	23,263	2b	Ha B2–3	Pieróg 2003; Kadrow 2003
Podłęże 17	ca 22,000	ca. 5,000	420	2b	Ha C–Ha D1	Dzięgielewski 2010; 2012a (U)

* Total number of ceramic units classified during material processing, not including the hard-to-classify approximately 2 million of briquetage 'lumps' – mainly from Form 2a cups.

** Total number of salt-making ceramic units from fills of archaeological features. For technical reasons, it was not entirely possible to separate the briquetage from the non-briquetage material in the cultural layers, therefore, in order to avoid confusion, it was decided to omit this set in the analyses (see previous footnote).

which, however, could have been redeposited from older Lusatian culture layers at this site[43].

A connection with the salt-making cannot be ruled out with regards to other ceramic objects either – especially deep ladles, known so far only from two copies from the late Bronze Age sites. These items could have been used to scoop salt molasses from large bowls of Form 1 and pour them into cups for portioning salt (Form 2). The ladle from site 11 in Kraków-Bieżanów (Fig. 7,11) has quite massive sleeve with an oval opening, flattened towards the scoop, with a reconstructed length of approx. 12 cm. It is made of ceramic paste tempered with crushed stone and sand, well fired, with a light to dark brick colour. In the front part of the scoop, from the outside, there are visible signs of a very strong secondary burning, and the inside of the scoop is badly damaged and worn away. The presence of a sleeve for mounting a wooden handle, which could have been used to manoeuvre the ladle over boiling water, and the context of the find (in a feature with a large amount of briquetage debris) suggests that this object is related to the process of brine evaporation. The only thing that raises doubts is the limited evidence of other finds of this type, with the exception of a very similar specimen from a neighbouring site – Kraków-Bieżanów 20[44], which, given the mass occurrence of the salt-making pottery at sites from the region near Kraków, only allows us to combine the ladles with the discussed activity hypothetically.

3.1.2.2 Macroscopic examination of ceramic technology

Due to the availability of materials for analysis (the sites examined by the authors of this study come from LBA and EIA) and the aforementioned problems with determining the relationship with the salt-making of bowl-shaped vessels, the technological analysis focused only on Forms 2a and 2b, as unambiguous briquetage. However, among the fragments included as Form 2a, some are certainly fragments of Form 1 beakers (see above). The macroscopic analysis of the vessel manufacturing technology has so far covered series with a total of over 28,000 ceramic units (single fragments or larger conjoining pieces of pottery, hereinafter c. u.) (Table 2), of which over 5,000 were analysed in detail for this project. The share of briquetage c. u. in the total number of pottery from individual sites seems high (it is almost 80 % for Kraków-Bieżanów 11, approximately 75 % for Brzezie 17, 61.75 % for Kraków-Bieżanów 27 and approx. 22 % for Podłęże 17). However, it is necessary to take into account the extreme degree of fragmentation and the low coefficient of refitting of forms in ceramics related to salt-making, and therefore its overrepresentation in relation to ceramic units representing ordinary kitchen- or tableware. Despite such proportions, none of the analysed settlements can in fact be considered a monofunctional production settlement, apart from the aforementioned Middle Bronze Age settlement from Kraków-Bieżanów 15, consisting almost exclusively of salt-making hearths[45]. (Pottery

43 The relationship of briquetage with the Pomeranian culture should also be rejected in the case of materials from site 19 in Kokotów, district Wieliczka (Matoga 2015) due to the necessary backward correction of the dating of this site in relation to the Matoga's proposal (more extensive justification in: Dzięgielewski 2024).

44 Matoga 2012, vol. 6.1 table VIIIa.

45 Przybyła 2010; 2015.

from this site – mostly Forms 1 – is not included into this analysis of technology.) Instead, we must acknowledge that at the Late Bronze Age and the Early Iron Age settlements analysed here, alongside salt-making, the regular life of prehistoric farming communities took place.

The macroscopic analysis of ceramics was performed only for fresh fractures, with the naked eye or with a magnifying glass (up to 8×), determining the percentage, granulometry and type of admixture to ceramic paste, using standards similar to percentage inclusion estimation charts by Mathew, Wood and Oliver[46]. Inter alia, admixture density, surface texture and colour, fracture characteristics and degree of fragmentation were recorded.

Preparation of the pottery fabric. The results of the macroscopic research of the technology confirm the apparently functional character of the analysed ceramics. This is mainly indicated by the massive use of poorly sorted, heterogeneous tempers, composed of crushed stone, grog, and less often sand. And so, among the two comparable series from the Late Bronze Age, from Brzezie 17 (BRZ17) and Kraków-Bieżanów 11 (K-B11), where Form 2a cups dominate (and the fragments of Form 1 beakers that are difficult to separate), 92.2 % (BRZ17) and 91.4 % (K-B11) are heterogeneous recipes, while this proportion is only 39.6 % and 43.6 %, respectively in the group of kitchenware from these sites (Fig. 11). One may also notice the lack of selectivity of the admixture in terms of grain size: individual fragments often contain numerous small crumbs (below 1 mm) as well as examples measuring about 5 mm. On the other hand, the preference related to the local availability of tempering raw material is visible: in the south-eastern outskirts of Kraków (Kraków-Bieżanów) covered with post-glacial alluvial-periglacial sands and Holocene sand alluvia, poorly sorted, fine or medium-grain crushed stone, mainly granite, mixed with grog were prevailing. At the same time in Brzezie, located on a loess plateau, devoid of a larger amount of natural stone, the basis of most recipes was clay (grog), usually with a smaller amount of crushed stone (Fig. 11). The differences between the sites also consist in the higher frequency of coarse-grained admixtures in Brzezie and fine-grained admixtures in Kraków-Bieżanów. It can be considered that they are the result of more general local technological choices in the pottery making, because where the use of fine-grained admixtures in ordinary ceramics was more common, they also predominated in salt-making pottery (Fig. 11). The temper density analysis confirms the opportunistic methods of production of briquetage. In

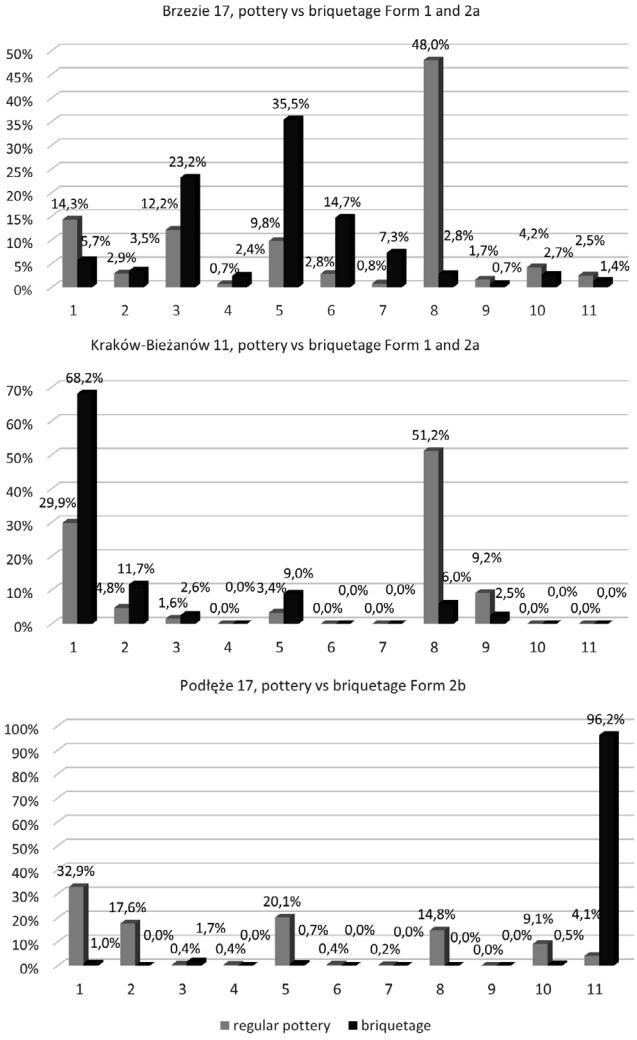

Fig. 11: Heterogeneity of tempers to clay matrix used for production of briquetage and regular pottery at settlements in Brzezie 17 (LBA), Kraków-Bieżanów 11 (LBA) and Podłęże 17 (EIA). Temper specification: heterogeneous tempers (1–7), grain size: 1 – crushed rock up to 1 mm and chamotte up to 1–2 mm; 2 – crushed rock up to 5 mm and chamotte up to 2 mm; 3 – crushed rock up to 2 mm and chamotte up to 5 mm; 4 – crushed rock larger than 5 mm and chamotte up to 5 mm; 5 – chamotte up to 5 mm and crushed rock up to 5 mm, less frequent sand; 6 – chamotte larger than 5 mm and crushed rock up to 5 mm; 7 – chamotte and crushed rock larger than 2 mm; homogeneous tempers (8–11), grain size: 8 – crushed rock up to 5 mm; 9 – crushed rock larger than 5 mm; 10 – chamotte up to 5 mm; 11 – sand up to 2 mm.

general, a greater amount of non-plastic additives to the paste facilitates the building (especially), drying and firing of the vessels, but reduces their durability[47]. Therefore, it should be expected that in ceramics intended for short-term, even single use, a dense admixture will prevail. And so, rare admixtures, occupying less than 10 % of the surface of the

46 After Orton/Hughes 2013, fig. A.4.

47 Cf. Gibson/Woods 1997, 30.

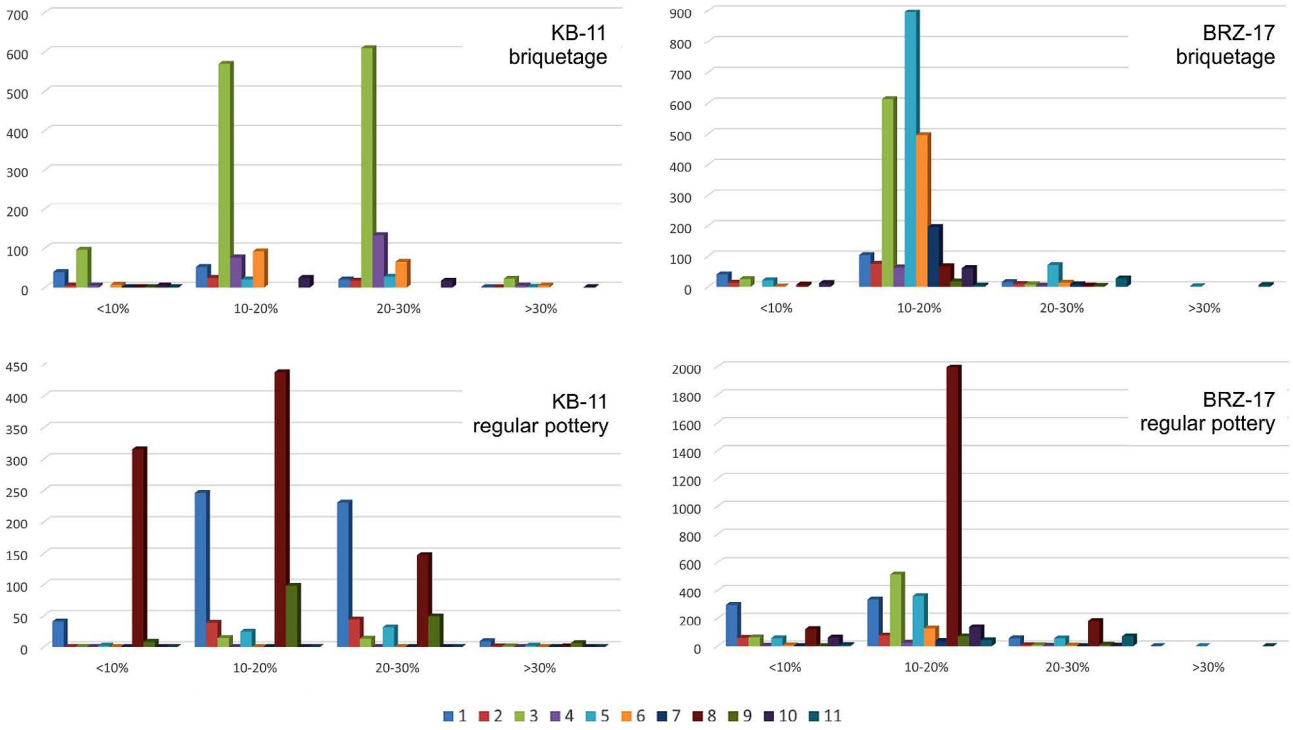

Fig. 12: Type and density (as % of surface of a fresh fracture) of tempers to clay matrix used for production of briquetage and regular pottery at LBA settlements Kraków-Bieżanów 11 and Brzezie 17. Temper specification as in Fig. 11.

fresh fracture, were found only in 4.1 % (Brzezie 17) to 8.0 % (Kraków-Bieżanów 11) of salt-making c. u., while in regular pottery from these sites this share was 14.0 and 20.8 %, respectively. In the case of Brzezie, this tendency is less marked, it is visible only as a higher proportion of the sparse admixture (less than 10 % in the fresh fracture) in the case of recipe no. 1, i. e. heterogeneous stone and chamotte admixture of grain size up to 1 mm (Fig. 12). This trend is clearly visible in Kraków-Bieżanów 11, where sparse admixture is visible not only in recipe 1, but especially in the homogeneous recipe 8 (crushed stone up to 5 mm) (Fig. 12). The proportion of vessels with a dense admixture (over 30 % surface of the fresh fracture), which is very rare in all recipes, is also slightly higher for salt-making ceramics (BRZ17: 0.27 %, K-B11: 1.89 %) than for other ceramics (BRZ17: 0.06 %, K-B11: 1.13 %) (Fig. 12). In the sample from Brzezie, many cases of uneven distribution of the admixture in the clay fabric were observed, which proves that the time spent on mixing clay with non-plastic material was not very long[48].

The younger cups Form 2b, on the other hand, had pottery mass with homogeneous non-plastic components. In Podłęże 17, 96.2 % of it was poorly sorted fine sand (with grains mainly up to 1 mm), while approximately 0.5 % was mixed with fine grog. In only about 3.5 % of c. u. tempered with sand, other inclusions were also found in the ceramic paste, such as fine grog, crushed stone or (extremely rare) organic debris (Fig. 11). A very similar structure (with no chamotte at all) was found in the collection from Kraków-Bieżanów 27[49]. The vast majority of briquetage tempered with sand had a very dense admixture at both the above-mentioned sites – always occupying 30 % and often even 50 % of the surface of the fresh fracture. In this respect, this category stands out from any other pottery known from the region, including Form 2a cups.

Vessel forming. Despite the enormous number of analysed fragments of briquetage, only a few general observations related to vessel building methods can be mentioned, regarding the severe fragmentation of the salt-making ceramic material (Fig. 13). In the case of Form 1 bowls, the routine coiling technique was certainly used. This is indicated by the average width of the fragments (up to several centimetres) and regular horizontal bands visible on the reconstructed vessels[50]. The same can be stated for the Form 2a cone cups. Their bottoms could be made of a single

48 Albero Santacreu 2014, 74.

49 Kadrow 2003, 217–218.

50 Matoga 2017, fig. 2,a.

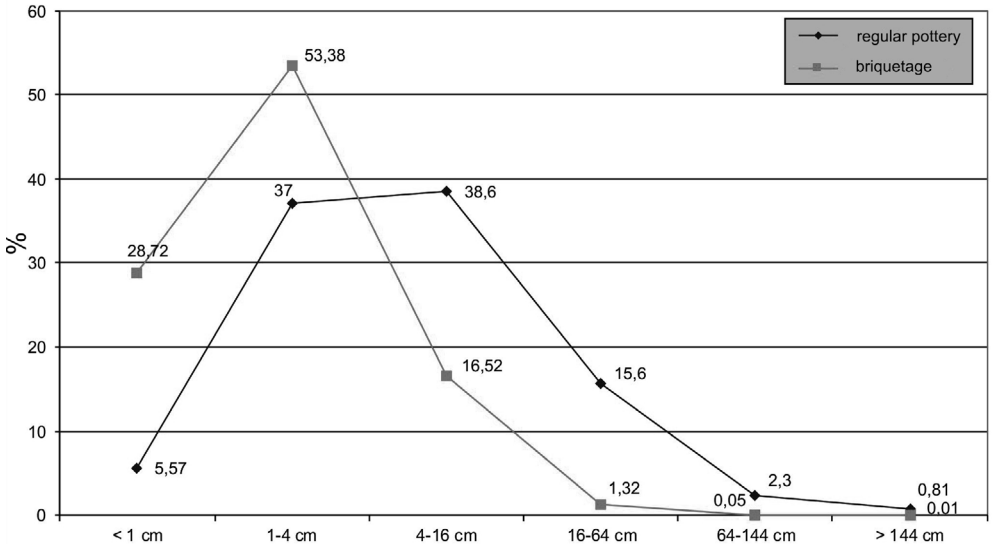

Fig. 13: Fragmentation of the salt-making ceramic in comparison with regular pottery from site 17 in Brzezie.

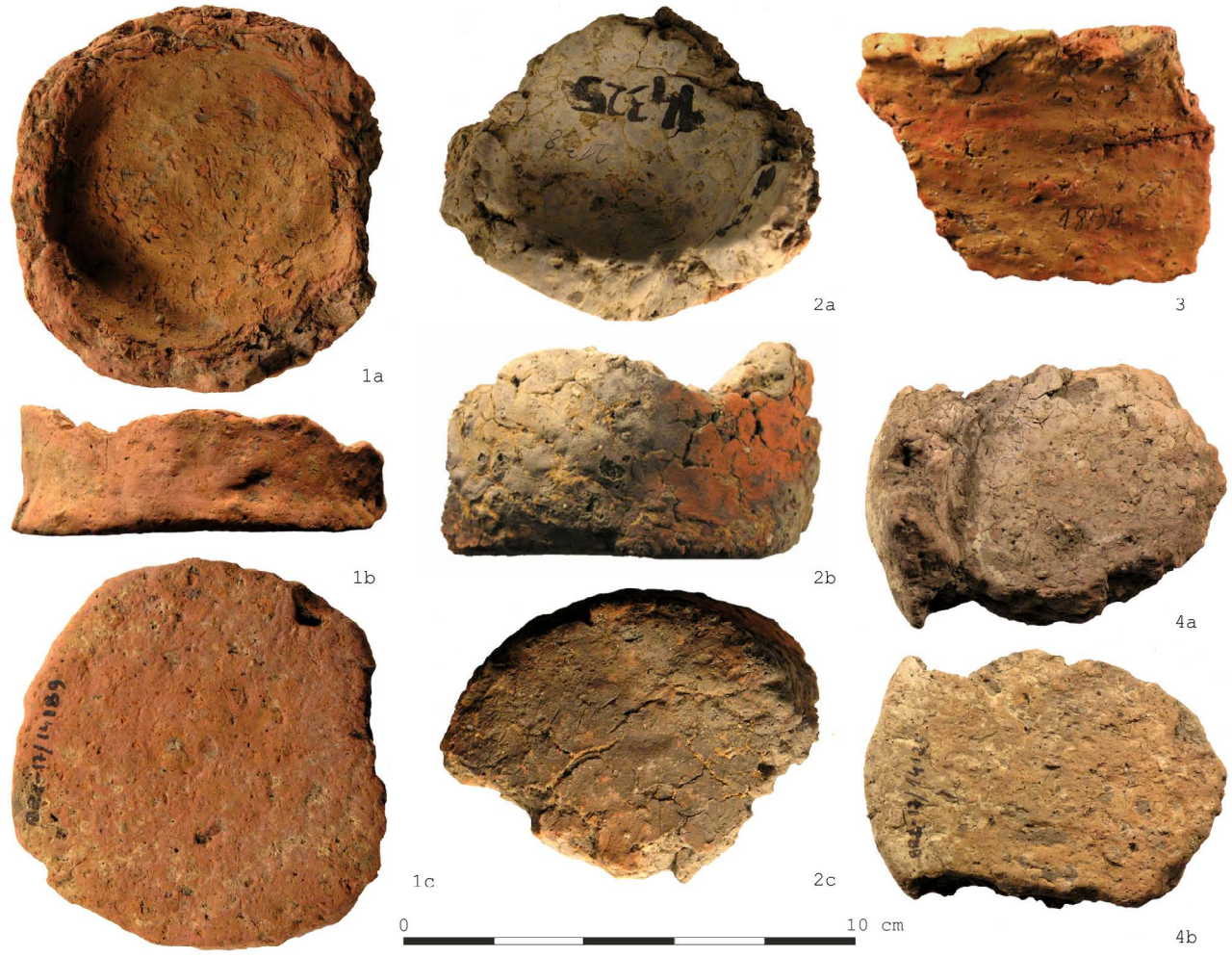

Fig. 14: Brzezie 17, examples of Form 2a cups: bottom (1,2,4) and upper (3) parts. Photo by K. Dzięgielewski.

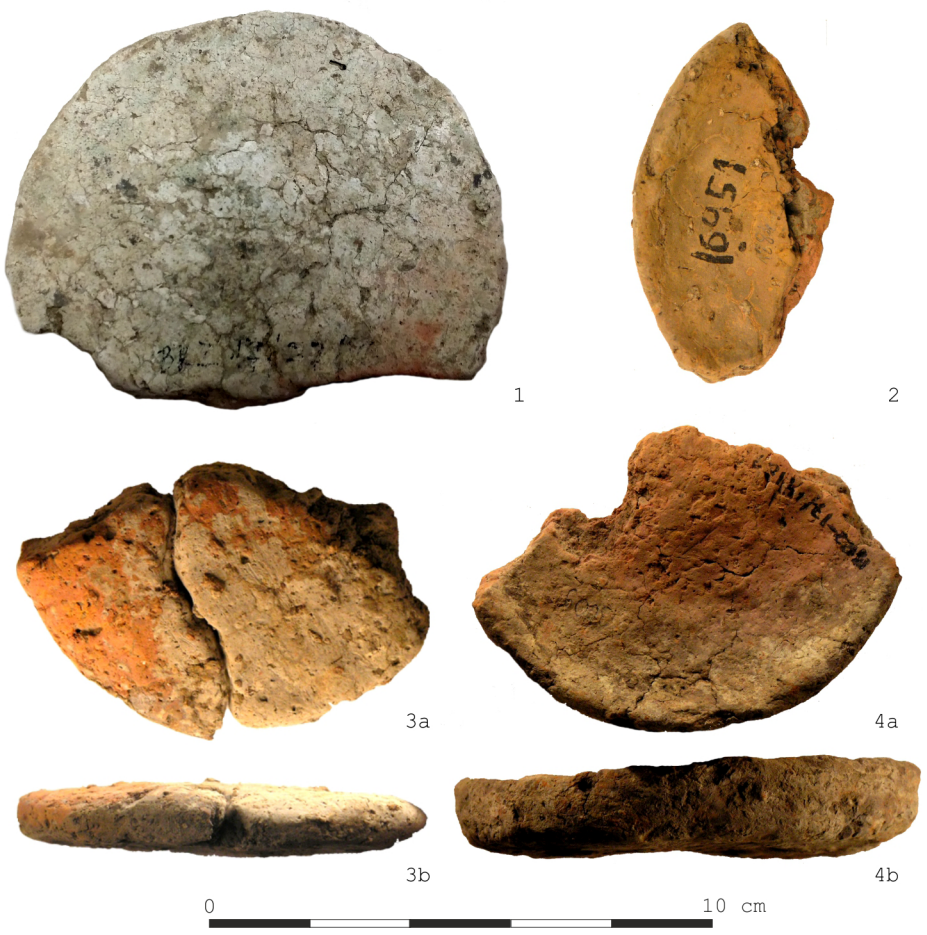

Fig. 15: Brzezie 17, examples of Form 3a pads. Photo K. Dzięgielewski.

piece of clay (traces of kneading), on which subsequent coils/strips were added. From the same piece of clay as the bottom, a base-like extension was also pulled out, forming a kind of foot (there are no traces of attaching it on the outside).

Form 2b chalice cups are characterised by a more diversified method of forming. At some sites, they were produced separately from two parts – a conical goblet and an attached foot. This technique was confirmed in Kokotów 19 and Kraków-Bieżanów 21 and 27[51]. It was described in detail by A. Matoga[52] based on materials from Kokotów. In the opinion of this author, after the the pointed body of the cup was modelled (and sometimes slightly dried), it was pressed into a flat disc of clay intended for the foot. This was probably done on a hard surface whereby the pointed ends usually flattened (unless the degree of dryness did allow this) (Fig. 19). The edge of the disc was then bent downwards to form a kind of foot, and its upper surface was gently connected to the body by smoothing it with the fingers, which left characteristic elongated fingerprints (Figs. 7,22–23). According to A. Matoga, this technique was used in the older phase of the production of Form 2b cups (Ha B – the beginning of Ha C; 950–700 BC)[53]. The two-part technique has so far been disclosed in a limited number of salt-making sites. However, it is not easy to distinguish it from the single-part technique without making a destructive cross-section of the fully preserved feet. For this reason, in the course of this study, the observations were limited to broken feet and a limited series of whole feet. In Podłęże 17 (Ha D), most of the lower parts of 2b cups indicated the technique of forming the bottom together with the foot from one rather thick piece of clay heavily tempered with sand, on which a thin-walled body was built (Fig. 16,2). Only individual specimens were made by attaching a foot to a tapered or flat-ended

51 Ebd. 150; Kadrow 2003, 217.
52 Matoga 2017, 142–146; 172.
53 See the arguments for the older chronology of materials from Kokotów in: Dzięgielewski 2024.

Fig. 16: Podłęże 17 (1–3) and Łuczyce 2 (4–5), examples of Form 2b chalice cups: upper (1) and bottom (2–5) parts. Photo by K. Dzięgielewski.

body (Fig. 16,3). It was noticed that the use of the latter technique (two-part) was accompanied by a higher degree of 'vaulting' of the feet (forming hollow base) (Fig. 19,1–2,4–6), while the feet of the one-piece specimens were low arched or even flat (Fig. 10,8–10.21–32; 16,2, 4). Determining the technique of making the middle and upper parts of goblets faces serious difficulties due to the negligible number of specimens preserved in this part (e. g. in Podłęże 17 out of 420 analysed c. u. only one specimen survived, which could be reconstructed from the rim to the bottom part). Probably, apart from the coiling technique, the slab (or flake) technique was also used, as evidenced by the characteristic structure of cracks in the upper parts of the goblets (Fig. 16,1). Traces of the coils/flakes were smoothed only to the extent necessary for their bonding. There were no traces of intentional smoothing or polishing of the surface, which, due to the extremely dense admixture of sand in the clay matrix, would not be easy. In the case of conical cups (Form 2a), the surfaces were sometimes smoothed, but very often due to the poor condition of secondary burned vessels, they are now severely worn (Fig. 17).

The only 'decoration' noted on the Form 2a cups were fingerprints or nail marks on the edges of the rims (Fig. 7,3.4.6; 8,4.8; 9,10–12.14–16; 14,3). The surfaces of the vessels were always unadorned, except for the finger smooths, which at least sometimes were simply a result of the final wall forming and not an ornament (Figs. 7,6.8–9; 17,2b). Traces of such treatments are also visible in the Form 2b cups[54]. The latter forms were completely devoid of ornamentation on the rims.

Pottery firing. At the sites we analysed, despite the wide-ranging nature of the excavations, no evidence of the presence of kilns or furnaces explicitly intended for the firing of salt-making pottery, as well as for other types of ceramics, was recorded. So, the vessels in question were most likely fired in bonfires or fireplaces. The vast majority of briquetage were fired in an oxidising atmosphere. Fractures without a core (single-colour), brick-red, dominate (Fig. 18), which is not surprising in the case of thin-walled cups (Form 2b), where the firing time did not have to be too long to ensure the complete burning of the organics from inside the wall, but it is not so obvious for Form 2a cups and Form 1 wide-mouth bowls with thicker walls. Only 25–30 % of salt-production ceramics are specimens with a two-colour cross-section (dark brown or grey on the inside), and approx. 10 % of a tricolour (red-brick with a dark core). The firing pattern of the remaining (regular) pottery from the analysed sites is slightly different – ceramics without a dark

54 Kadrow 2003, 217.

Fig. 17: Kraków-Bieżanów 11, completely reconstructed Form 2a cups. Photo by M. Mazur.

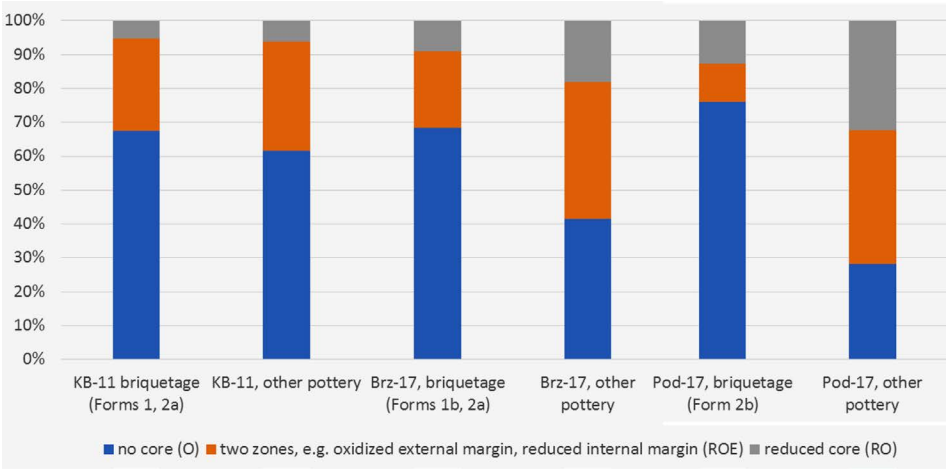

Fig. 18: Colours in cross sections in briquetage and in regular pottery. Acronyms (O, ROE, RO) according to Eramo and Mangone's (2019) visual scheme.

core, fired long enough to lose traces of organic material from the inside of the walls, is about 30–40 % of a given series. The most striking difference between salt-making and regular pottery forms is visible at the site 17 in Podłęże, where single-colour firing dominates among briquetage, while among the remaining ceramics, two-coloured and three-coloured specimens are dominant. At the site 17 in Brzezie, forms with a two-colour cross-section in non-salt-making ceramics were recorded twice as often as in briquetage, while the least difference between the types of ceramics is visible at site 11 in Kraków-Bieżanów (Fig. 18). The question of what causes these differences remains open. Certainly, the differences in the firing degree may to some extent be the result of multiple secondary firing of the briquetage during the evaporation of brine[55]. The lower proportion of shards with a two-colour fracture, reduced from the inside, in the group of salt-making ceramics may,

55 Cf., however, Alessandri *et al.* 2019, 4.

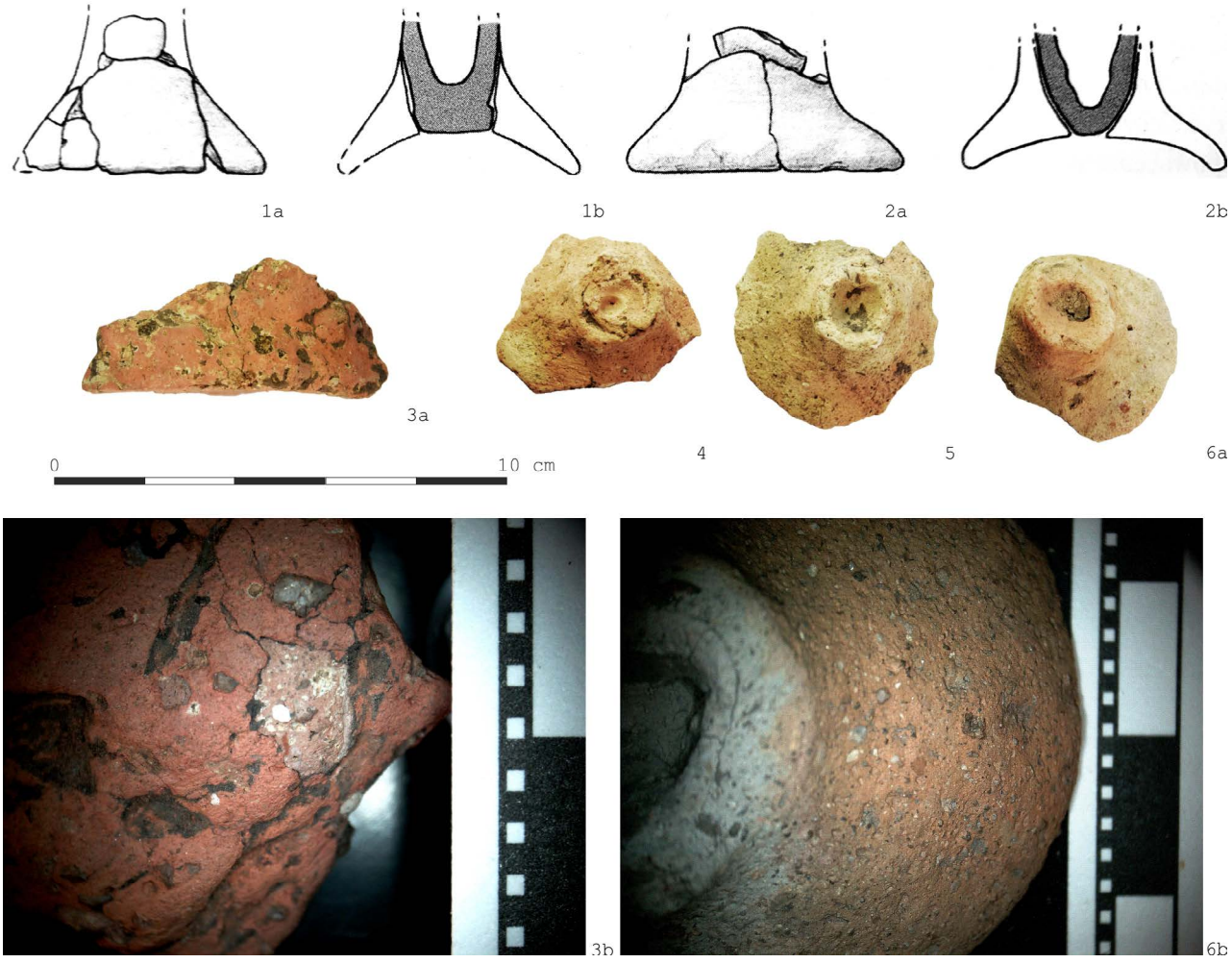

Fig. 19: Technological details of the briquetage from Małopolska: Form 2b chalice cups from Kraków-Bieżanów 20 (1–2) and Wieliczka 112 (3–6); examples of heterogeneous, 'multi-generational' temper (grog in grog) in Form 2a cup (3), and homogeneous, sand temper in Form 2b chalice cup. According to Matoga 2017 (1–2). Photo by A. Maślak, courtesy Cracow Saltworks Museum in Wieliczka (3–6).

in turn, indicate that they were not often fired upside down or stacked[56]. Such a finding in the case of mass production purposes is somewhat surprising. Therefore, it should be assumed that they could have been fired in stacks, but most of the ceramics had walls that were so thin that they burned evenly through despite the limited access of oxygen to the vessel interior. In thin walls, oxygen could operate evenly, regardless of whether it was accessible from the inside of the vessel. However, this assumption requires experimental confirmation. For now, it is to some extent supported by the observation that these vessels must have been relatively well insulated from the fuel during firing due to the relatively rare presence of dark 'fire clouds' on their surfaces. It seems that this could have only been achieved in an open or depressed fireplace through cumulative firing.

3.1.2.3 Conclusions from the petrographic analysis

Samples for petrographic analyses, aimed at verifying the findings made on the basis of macroscopic research, were selected from three sites: Kraków-Bieżanów 11, Brzezie 17 and Podłęże 17. The research was carried out by Michał Borowski as part of the project 'Inheritance, social network or local adaptation? Bronze and Early Iron Age societies in western Małopolska', and their results were presented in a detailed report[57] and in an archaeometric article being prepared for press. Comparative tests were also carried out on samples of non-salt ceramics from the same contexts. The methods used are standardly applied in mineralogical and petrographic studies of technological aspects of archaeological ceramics: polarised-light optical microscopy (POM) of thin sections, description of clay body – matrix

56 Cf. Orton/Hughes 2013, 73.

57 Borowski 2020.

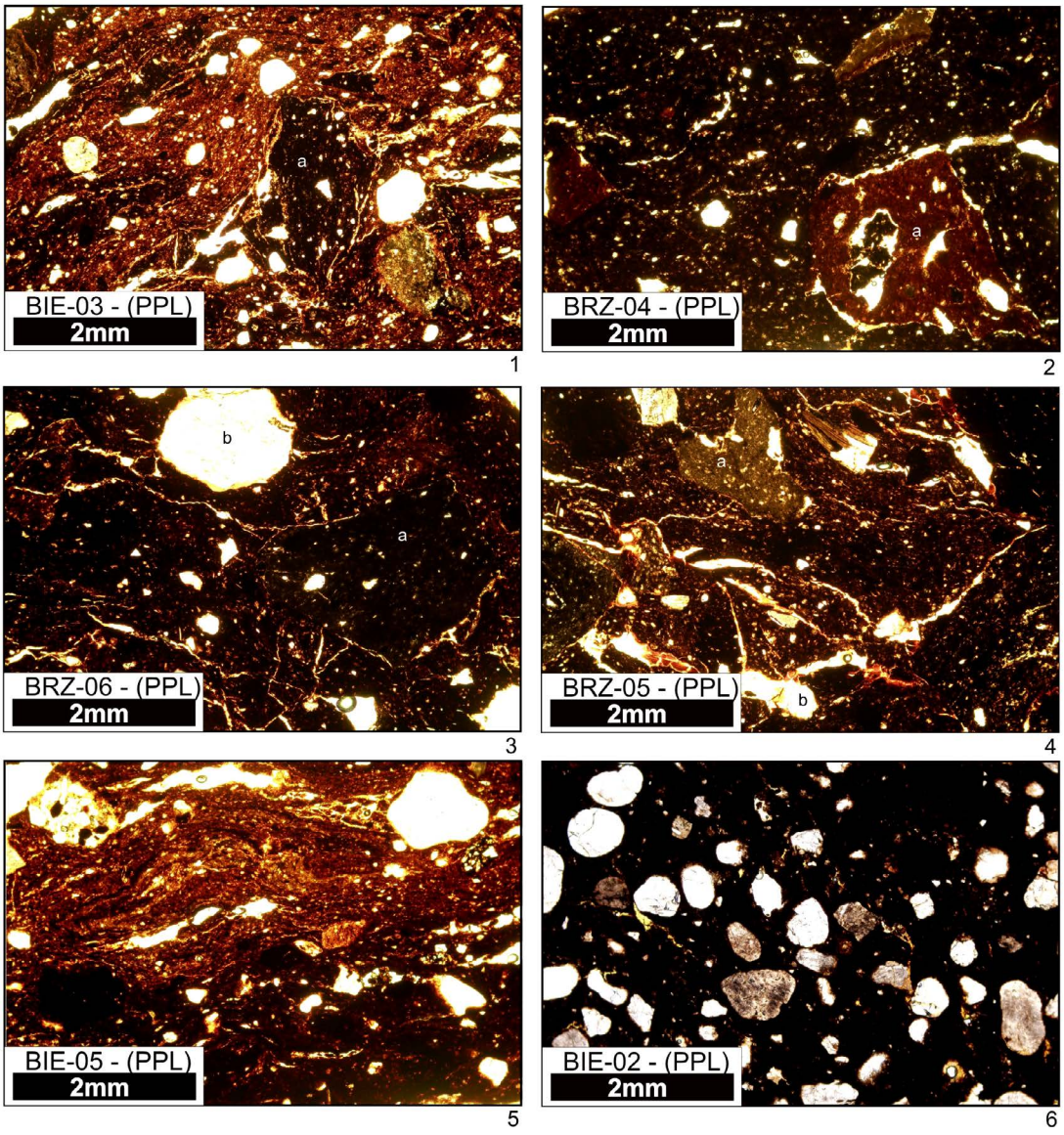

Fig. 20: Microphotographs showing the general view of the ceramic matrixes of Late Bronze Age salt-making pottery – Forms 2a from Kraków-Bieżanów 11 (BIE) and Brzezie 17 (BRZ). Photo by M. Borowski.

and non-plastic components NPIs, porosity and secondary changes.

Clay raw materials with considerable amounts of iron were used for the production of briquetage from the sites in Brzezie and Kraków-Bieżanów, constituting from 55 to 72 % of the clay paste, characterised by a varied content of natural NPIs[58]. Three types of readily available tempering inclusions were added to the clayey matrix: grog (a crushed ceramic) and chamotte (a calcinated clay intentionally produced to be crushed)[59], crushed stone (granitoids, probably of erratic origin), and sand. The above-mentioned components are present in the tested samples of ceramics in strongly different volume proportions and with various degrees of fragmentation, which indicates a certain lack of standardisation in the production process. Crushed pottery (grog) was the most commonly used admixture, as evidenced by its presence in almost all analysed samples. The consistent use of this tempering component over the years is clearly indicated by the multi-generational nature of the fragments of recycled ceramics ('grog in grog') (Fig. 20,1, cf. 19,3).

Based on the conducted petrographic research, several types of ceramic fabric were distinguished in the tested set of salt-making pottery (mainly Form 2a), differing in the

58 Ibid. table 1.

59 For a distinction of both see Eramo/Mangone 2019, 6 fig. 4.

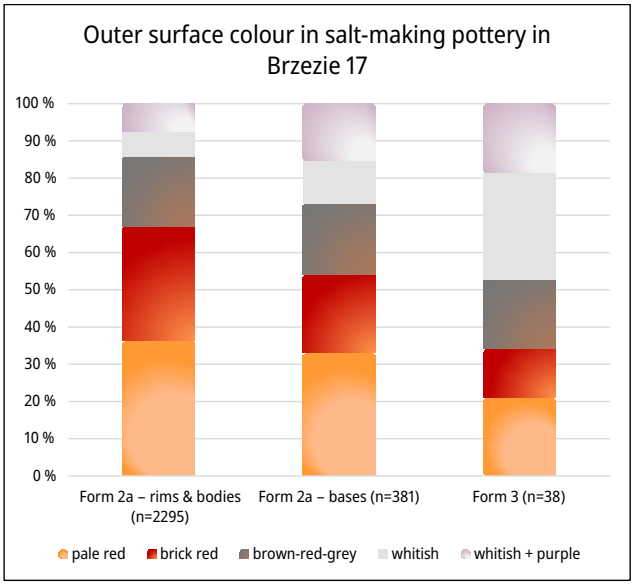

Fig. 21: Outer surface colours on Late Bronze Age salt-making pottery from Brzezie 17.

type and amount of deliberately added admixtures: Type I – 'fabric very rich in grog' with a particularly high proportion of fragments of recycled ceramics (about 12–23 % by volume, see 'a' in Fig. 20,1.2); Type II – 'fabric rich in grog and crushed stone' with a moderately high content of fragments of recycled ceramics (about 9–12 % by volume, see 'a' in Fig. 20,3.4), accompanied by significant amounts of crushed stone ('b' in Fig. 20,3.4); Type III – 'fabric rich in mineral admixtures', samples of various composition, characterised by a low content of grog at most (less than 5 % by volume) and the leading role of other types of admixtures, such as crushed stone or sand (Fig. 20,5), including a well-sorted sand (Fig. 20,6).

The distinguished types should not be equated with any specific 'recipes' used by the pottery manufacturers. On the contrary, it seems that one should rather talk about a general lack of standardisation of the composition of pottery masses used in the production of briquetage, which confirms the conclusions drawn from macroscopic analyses of the composition of pottery fabric. If further, more extensive petrographic research is undertaken, the occurrence of samples with a transitional composition, showing features intermediate between the distinguished types, can be expected. This is clearly evidenced by the results of macroscopic studies presented above. Perhaps an exception to this is the type of temper illustrated in Fig. 20,6. There are clear similarities of this subtype to the 'sandy' type of fabric of Form 2b cups, identified only in macroscopic studies (see Chapter 3.1.2.2). It seems that the lack of standardisation of the ceramic pastes, as well as the repertoire of NPIs itself, based mainly on three types of tempering materials, can be considered typical not only for briquetage, but to some extent also for all coarseware in the pottery workshop of the Lusatian culture community in the area of Małopolska[60].

Based on the results of petrographic analyses presented here briefly, which covered only slightly more than 20 fragments of vessels from three sites[61], it can be assumed that in the production of ceramics, apart from the basic tempering component, which was grog, crushed stone was also used, mainly in Brzezie. In Kraków-Bieżanów, the use of this component seems to be less widespread, contrary to the conclusions of the macroscopic analysis of ceramic masses presented in section 3.1.2.2, which shows that fine crushed stone (up to 1 mm) is the basic component of the masses at this site (Fig. 11). This may suggest that grains identified macroscopically as very fine crushed stone are in fact sand. However, the validity of this conclusion should still be verified by microscopic examination of a larger number of shards from both locations.

3.1.3 Utilisation of vessels in the salt-making process: identification of traces of use

As mentioned in the formal analysis of the vessels, one of the direct pieces of evidence of use of the described ceramic forms is the secondary burnout of individual vessels and their parts. The most severely burned was the pads (Form 3), which were probably constantly in the embers. In Brzezie 17, almost 50 % of them had surfaces showing signs of strong secondary burnout to a whitish or whitish-blueish colour (Fig. 21, see also Figs. 14; 15). The bases and the bottom parts of the Form 2a cups showed such traces in almost 30 %, while among the fragments of the brims and the middle parts of the cups such a condition was found only in 15 % of cases. Numerous secondary cracks were visible on the burned surfaces (Figs. 14; 15). This is one of the types of evidence for the long-term and repeated use of the pads in the process of brine thickening in the fire of hearths and for direct contact, especially of the lower parts of the Form 2a cups with fire and fuel.

60 See, for example, Korczyńska *et al.* 2018, 151–154.
61 Cf. Borowski 2020.

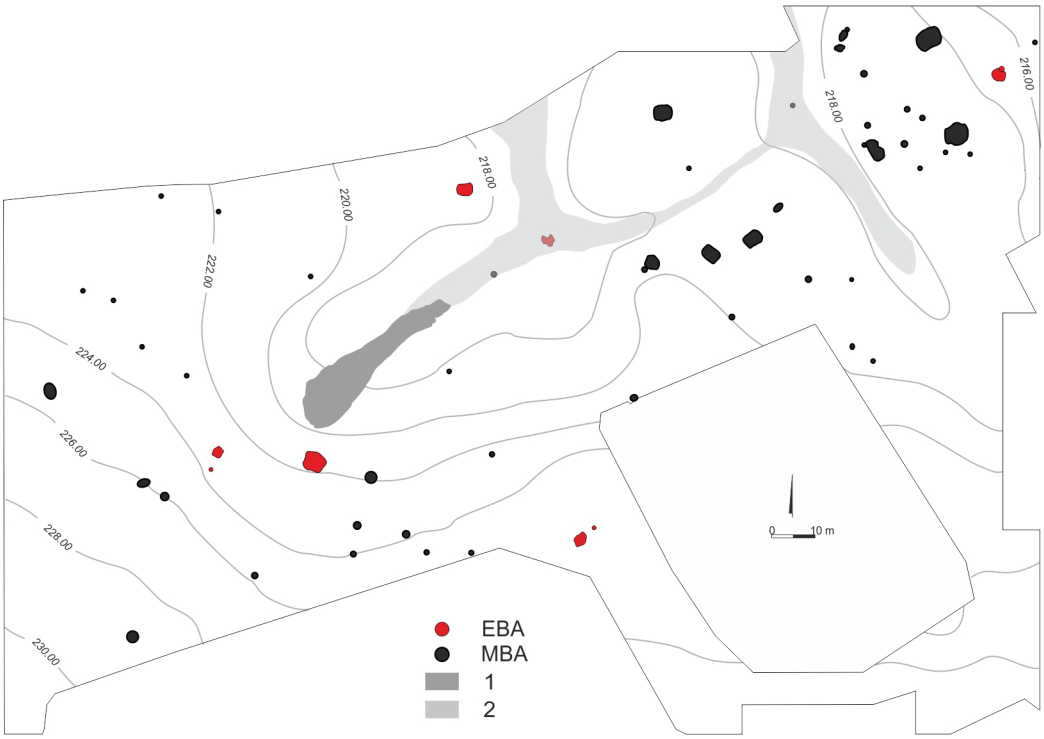

Fig. 22: Kraków-Bieżanów, site 15. Fragment of the central part of the production settlement with relics of salt-making installations (primarily hearths) marked red for the Early Bronze Age and black for the Middle Bronze Age. Grey outline marks of the excavated paleochannel of a salty spring active during MBA (1) and the reconstructed course of the non-preserved watercourse (2). According to M. M. Przybyła 2017, fig. 8, modified.

3.2 Salt-making sequence

3.2.1 Acquisition of salt water and initial (container-less) evaporation of brine

The saline water was obtained directly at the back of the test sites. The riverbeds or palaeochannels, or the springs and effusions of water with probably low natural salinity resulting from geological conditions, changing during the studied period of time (cf. Chapter 2), were located at a distance of no more than 10–150 m from the boundaries of the settlements where traces of salt-making were confirmed (Figs. 22; 23). Probably preliminary (container-free) evaporation of the brine took place in the low-situated spaces between the saltwater sources and the residential areas. In the literature on the region near Kraków, there is a suggestion to link some groove structures and clarifiers, especially those related to the Neolithic period with the initial evaporation of salt water[62]. As part of the presented project, as well as during other new studies, no such structures related to the Bronze Age and the Early Iron Age were found, which makes it impossible to refer to or possibly verify the findings of earlier discoveries. Although groove objects with an unexplained function were discovered at the sites studied (e. g. in Kraków-Bieżanów 11[63]), they were located in a zone away from saltwater sources and are probably not related to the process discussed here. In addition to the hypothetical collecting of salt water (which seems necessary, for example, due to the need to purify the solution by decantation) and initial evaporation near sources, its transport to residential areas in containers can certainly also be assumed. This is evidenced by the presence in these areas of large vessels used to evaporate the brine (Form 1 bowls).

3.2.2 Evaporating brine with the use of fire

At none of the examined sites was salt found to have been obtained solely by evaporation in the sun or by leaching without ceramic containers, as in Italy[64], for example. The majority of the brine evaporation process took place here at high temperatures, in hearths. This process was best traced at site 15 in Kraków-Bieżanów, where almost all immovable

62 Jodłowski 1971, 111 fig. 24; 1976, 146–147 fig. 26.

63 Mazur 2012.

64 Cf. Sevink *et al.* 2021.

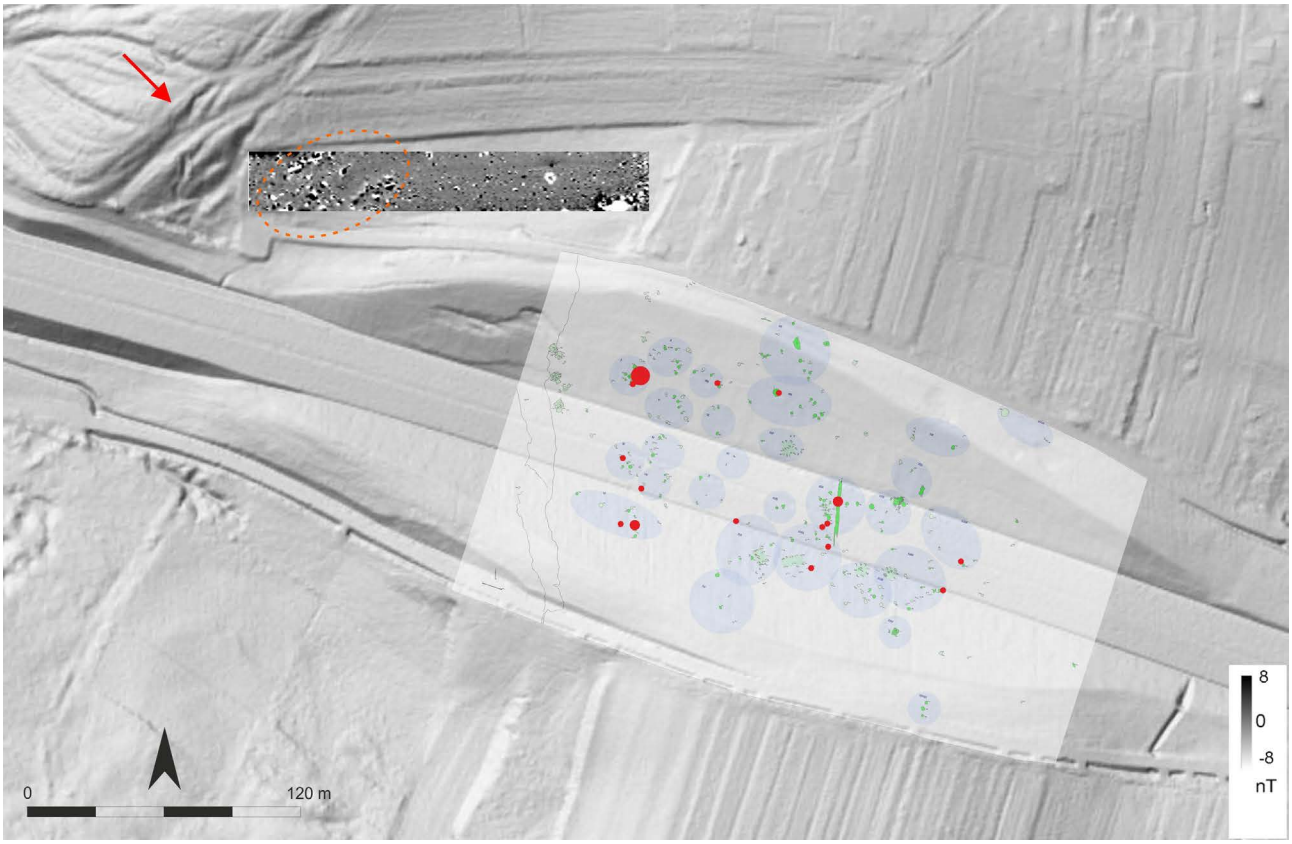

Fig. 23: Brzezie, site 17. An outline of the excavated part of the Late Bronze Age (Hallstatt A) settlement and geomagnetic surveys against the background of the LIDAR imaging taken after the construction of motorway A4. The red arrow marks the alleged salty springs, red dashed line – the potential hearths, blue ovals – supposed household units, and red circles mark finds of Form 3a pads which indicate the distribution of households involved in salt portioning. Compiled by K. Dzięgielewski

archaeological objects from the Middle Bronze Age (associated with the Trzciniec culture) were linked with this stage of the production process[65]. During excavations at other sites, e. g. in Kraków-Bieżanów 11, salt-making hearths in low-lying zones were also found (Fig. 24). In Brzezie, the existence of supposed fireplaces near the occurrence of saltwater effusions has so far solely been suggested by geomagnetic studies (Fig. 23). However, it was only in Kraków-Bieżanów 15 that it was possible to grasp the broad environmental context of these objects, as there was found a fragment of a paleochannel of the watercourse functioning in the Bronze Age, on both banks of which stood lines of hearths[66] (Fig. 22). The relics recorded at both sites from Bieżanów (11 and 15) were the remains of large oval dug-in hearths, with thick layers of charcoal and ash located in parallel belts on both sides (Fig. 24). Such structures could have functioned as three-part installations for the evaporation of brine, which was also confirmed by an experiment carried out in 2010 at the Archaeological Museum in Kraków[67]. This test showed that the size and arrangement of these structures allowed for the simultaneous pre-evaporation of brine from a large number of vessels (Form 1 wide-mouth bowls) placed near the fire in the space between the fireplaces (Fig. 6,2). On the other hand, Form 2b cups with already pre-concentrated salt molasses could have been placed in the fire at the same time. The experiment did not prove that the first of these thickening stages was very effective. Better results (shorter evaporation time) were achieved for Form 1a bowls with holes under the rim, through which straps were threaded, hanging directly over the fire[68]. The construction of three-part fireplaces, with a space devoid of fire in the middle, made it possible to both place the bowls near the embers, hang them over the fire, and insert cups into the fire itself (Fig. 6,1–2). Therefore,

65 Przybyła 2010; 2015, 176–178 fig. 6; Przybyła M. M. 2017, 374–375.
66 Ibid. fig. 18.
67 Przybyła 2015.
68 Ibid. 174.

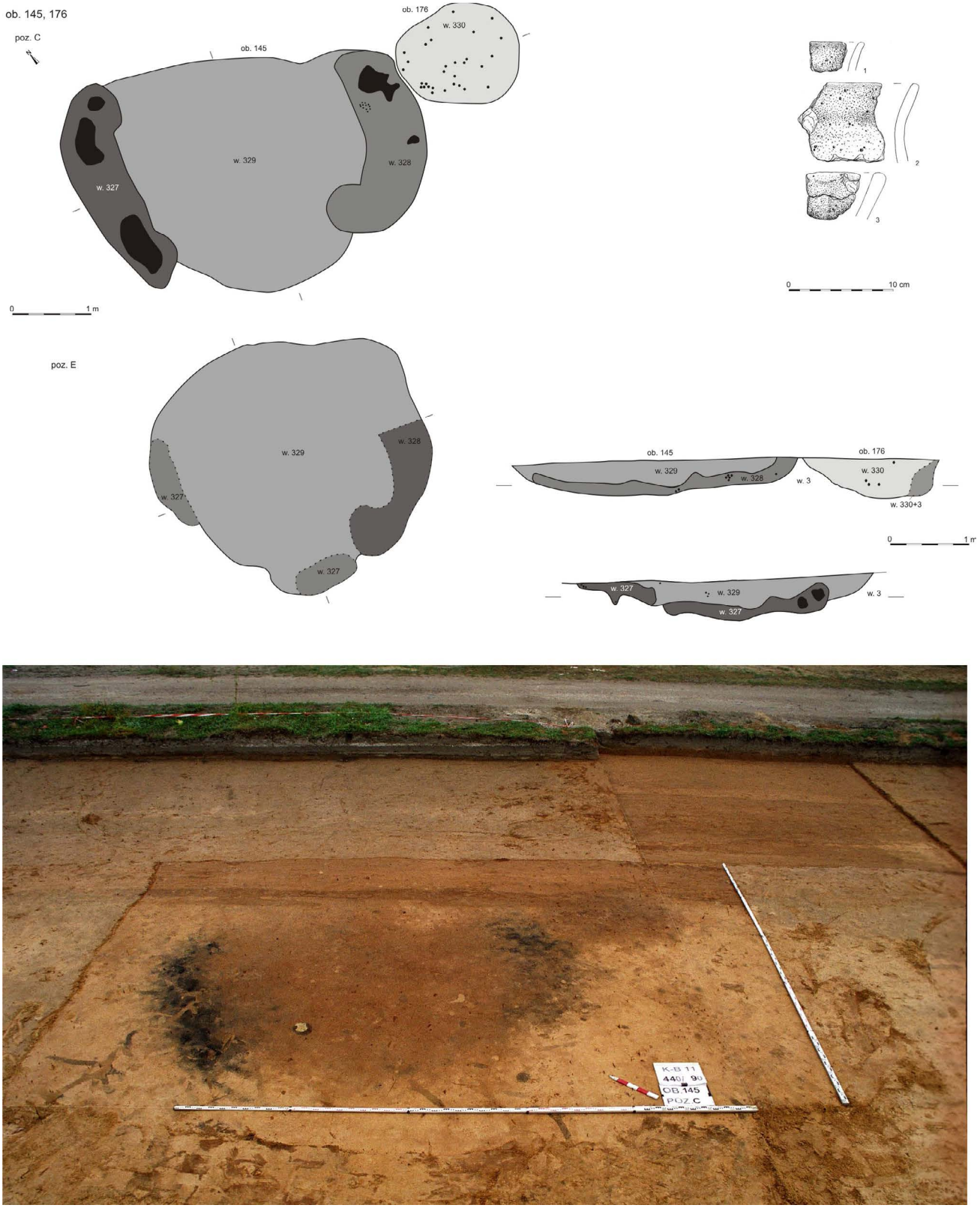

Fig. 24: Kraków-Bieżanów, site 11. Plans and cross-sections of Late Bronze Age hearths for salt brewing (features no. 145 and 320). Photo by J. Fraś.

these were devices enabling a very efficient use of fuel (as indicated by the data for Kraków-Bieżanów 15, mainly oak wood[69]). The use of these specific hearths is confirmed in the area near Kraków from the Early (KB-15), through the Middle (KB-15) to the beginning of the Late Bronze Age (KB-11, KB-15)[70]. Taxonomically, the accompanying non-briquetage pottery in these facilities should be linked with the Mierzanowice, Trzciniec and the Early Lusatian cultures, respectively. Waste pits saturated with debris of damaged ceramic material (used Form 1 bowls and Form 2a cups) were found near the furnaces at KB-11. It is possible that other furnaces were also used to evaporate the brine – including ordinary fires or hearths within households. This is especially true of sites where the presence of salt ceramics has been confirmed, but no specialised hearths have been disclosed. In fact, these are all sites younger than Ha A2 where the larger Form 2a cups have been replaced by the smaller Form 2b cups.

3.2.3 Drying and portioning of salt

Salt molasses, evaporated on fire in the wide-opening Form 1 vessels, were dried similarly to most of the inland salt making regions in this part of Europe[71] – including in furnaces of various shapes, with the use of smaller containers (Forms 2). Molasses could have been transferred between containers by pouring a semi-liquid mass or – in the case of thicker masses – by dosing with wooden or clay scoops. Potentially, deep ladles, such as those found in Kraków-Bieżanów 11 and 20, could potentially have been used for this purpose (Fig. 7,11; their connection with salt making is not, however, indisputable, cf. chapter 3.1.2.1[72]). The vessels with the molasses were replenished as the molasses discharged water until a homogeneous, dry salt precipitate was obtained. In the Early and Middle Bronze Age, the molasses must have been dried in the same containers as the evaporation of the brine (Form 1 bowls). Therefore, the portioning of salt – if it took place at all – was not related to the form and capacity of the container. Only the use of Form 2 cups at the onset of the Late Bronze Age made it possible to obtain standard portions of salt in the process of final drying of the molasses. The size of these portions, due to the very small series of fully preserved specimens, can only be reconstructed approximately. The calculation of the capacity of the briquettes does not encounter any major problems, due to the fact that their interiors are represented by quite regular solids in the shape of a truncated cone[73]. A bigger obstacle is the fact that we have only a small series of fully preserved specimens. There are only three true ('non-drawing') cases of reconstruction of full profile of Form 2a cups (Kraków-Bieżanów 11) (Fig. 7,8–10; 17) and also only a few cases of actual (from the foot to the rim) reconstructions of Form 2b chalices (Biskupice 1 (Fig. 8,26)[74]; Kraków-Bieżanów 15[75]; Kokotów 15[76]). On this basis as well as several fairly reliable drawing reconstructions, we calculated (Table 3) that Form 2a cups had an average capacity of approx. 1.2 l, and Form 2b – approx. 0.3 l. Assuming that due to granularity and the degree of compacting, the density of the salt obtained then was lower (1.1 g/cm^3) than modern table salt (1.2–1.4 g/cm^3)[77], the first of them held an average of 1.35 kg, while the second – about 0.33 kg of the final product.[78] If it were assumed that the upper sections, the most wide-mouth parts of approximate 1 cm high, were not filled with salt, these figures would be correspondingly smaller (Table 3; Form 2a: approx. 1 l; Form 2b: 0.2 l). However, in the light of the experiments, such assumption seems unlikely (Fig. 6,3–4).

3.2.4 Separating salt from containers

Salt could have been separated from wide-mouth containers (Form 1) either by pouring or scooping it in a semi-liq-

69 See Dzięgielewski *et al.* 2024b, table 2.

70 Przybyła 2015, 173–176 fig. 5.

71 Jodłowski 1976, 156; Harding 2014, fig. 4.

72 See also Weller/Ard 2024, fig. 11.

73 Cf. Tencariu 2018; Alessandri *et al.* 2019, fig. 18.

74 See Gedl 1968, fig. 4d; Jodłowski 1976, photo 2 [second from the left]; Bukowski 1988, Abb. 8,2 [second from the left]. Due to the technical quality of the documentation and the drawing manner, it is not certain whether the drawing published by M. Gedl is identical to the vessel in Jodłowski's photograph and to the vessel (actually reconstructed) present today at the Cracow Saltworks Museum in the Wieliczka Salt Mine. Other drawing reconstructions of 2b cups functioning in the cited literature do not have any support in actually preserved archaeological material. This applies to specimens from: Kraków-Tyniec (Jodłowski 1976, fig. 11,ł); see the original state of preservation in: Dymek 2002) and from Kraków-Barycz, district Wieliczka – the alleged barrel-shaped goblet with inverted rim (cf. Jodłowski 1976, Abb. 11,i; Bukowski 1988, Abb. 2 [first from the left]; Przybyła 2015, fig. 7,22); the history of this erroneous reconstruction, which is the result of a mechanical combination of drawings of two different vessels, is discussed in Fraś/Kolebuk 2019, 65–67 fig. 8.

75 Przybyła 2015, fig. 7,23.25.

76 Fraś/Kolebuk 2021, fig. 12,14.

77 Cf. Moinier 2011, 138.

78 Taking into account a number of initial uncertainties and measurement errors (manual, careless building, the state of preservation of the material, the manner of documentation and publishing, etc.), no further procedures aimed at refining these values were used in the calculations (cf. Rodriguez/Hastorf 2013).

Tab. 3: An attempt at estimating the volume of salt-making vessels and the corresponding weight of salt obtained in them.

Specimen_site	Form	r1	r2	H	Full volume (to the rim)		Less volume (1 cm below the rim)		Reference
					V (litres)	Weight of NaCl (kg)	V (litres)	Weight of NaCl (kg)	
1_KB-15	1a	15,5	7	16,5	6,87	7,55	5,96	6,56	Przybyła 2012, pl. 38,1; 2015, fig. 6,9
2_KB-15	1a	16,5	5,5	15,5	6,38	7,02	5,48	6,03	Przybyła 2012, pl. 202,15
Mean V (l) and weight (kg) of salt in Form 1a					**6,63**	**7,29**	**5,73**	**6,3**	
3_KB-15 (atypical)	1a	12,5	3,5	10,5	2,33	2,56	1,87	2,06	Przybyła 2012, pl. 367,2; 2015, fig. 7,1
1_Wie-104	1b	19	6	38	20,33	22,37	18,37	20,2	Fraś/Kolebuk 2021, 262 fig. 2f
1_KB-11	1b	15,5	5	23,5	8,43	9,27	7,36	8,1	Mazur 2012
1_KB-20	1b	18	6	27	13,23	14,55	11,78	12,96	Matoga 2017, fig. 2a
Mean V (l) and weight (kg) of salt in Form 1b					**14**	**15,4**	**12,51**	**13,76**	
2_KB-11	2a	6,2	3,06	15,7	1,1	1,21	0,85	0,94	Mazur 2012, feat. 896
3_KB-11	2a	7,25	2,7	14,2	1,18	1,3	0,91	1,00	Mazur 2012, feat. 897
4_KB-11	2a	6,1	2,5	14	0,86	0,95	0,65	0,71	Mazur 2012, feat. 1339
1_Brz-17	2a	7,5	3,75	17,5	1,8	1,98	1,46	1,6	Dzięgielewski 2012, feat. 1362
Mean V (l) and weight (kg) of salt in Form 2a					**1,24**	**1,36**	**0,97**	**1,06**	
1_KB-27	2a/2b	5	2,5	18,5	0,85	0,93	0,64	0,7	Kadrow/Nowak-Włodarczak 2003, fig. 6,2
1_Bis-1	2b	4	1	15	0,33	0,36	0,20	0,23	Gedl 1968
1_Bar-5	2b	5,75	0,8	17	0,68	0,75	0,46	0,51	Fraś/Kolebuk 2019, pl. IV,12
1_KM-62	2b	3,75	0,8	10,6	0,19	0,21	0,11	0,12	Bazielich 1992, fig. 37,1
1_Zak-1	2b	4,5	0,8	10	0,26	0,28	0,16	0,17	Przybyła/Chudzińska 2012, pl. 17,4
3_KB-15	2b	4,8	0,9	10,3	0,30	0,33423	0,19	0,21	Przybyła 2012, pl. 359,1; 2015, fig. 7,23
4_KB-15	2b	2,8	0,5	5,6	0,06	0,061217	0,023556	0,03	Przybyła 2012, pl. 388,3; 2015, fig. 7,25
1_Kok-15	2b	4	1	12	0,26	0,29	0,16	0,18	Fraś/Kolebuk 2021, 281 fig. 12,14
Ideal_2b	2b	4	1	14	0,31	0,34	0,19	0,21	various sources (average)
Mean V (l) and weight (kg) of salt in Form 2b					**0,30**	**0,33**	**0,19**	**0,21**	

uid state or by scraping off the dry sludge. With their large capacity and some caution, these containers may have been used multiple times. This might to some extent explain the low frequency of these forms in the younger sections of the Late Bronze Age and the Early Iron Age (perhaps as Form 1c – cf. Fig. 5), although they undoubtedly must have been used in the first stage of brine densification. Unlike large, reusable vessels, extracting salt cakes from narrow conical containers required more complex procedures. Quite massive and heavy (about 0.5 kg of ceramics) Form 2a cups could not have been the final packaging for salt. Moreover, their removal on site is evidenced by the unusually large amounts of waste in the excavated settlements (see Chapter 3.2.5). Experiments based on similar containers from Romanian Moldova[79] provided a lot of data on the methods of extracting salt from such moulds. In the study cited, it was shown that in order to obtain a solid block of salt, thermally dried brine had to be highly concentrated before being placed in the mould (almost completely evaporated) and probably also mechanically pressed to remove excess water and air channels during final evaporation. Tencariu *et al.* also showed that an efficient way to remove the briquette as a whole was to add insulating layers to the inner walls of the mould before drying the brine in the fire. In the described experiments, animal fat and leaf coatings

79 Tencariu *et al.* 2015.

were used: both were equally effective, although the latter would quite significantly reduce the capacity of the vessel[80]. No macroscopic traces of this type of substance have been found in the material near Kraków, and the research on lipid residues has not yet been included in the presented project. As in the cited study from Romania, this detail is still waiting for archaeometric confirmation.

The situation is different with the more delicate, thin-walled cups of the Form 2b. It was probably possible to extract salt briquette from these tall and narrow containers after breaking them, but it must have been much more burdensome to add an insulating layer of fat on the inside.[81] On the other hand, a leaf cladding would have effectively reduced the volume of these already small containers. Therefore, it seems likely their thin walls could, at least in part, have constituted the final packaging of the product, perhaps after removing just the foot, which mainly served its function during the thermal drying stage in the hearth[82]. This is evidenced by the fact that on evident production sites, fragments of bottoms with feet are clearly overrepresented in relation to the rims and bellies of Form 2b (in Kraków-Bieżanów 27, the fragments of feet amounting to 40.75 %[83]).[84] At the Podłęże 17 site, which was rather non-productive, but was located near the salt-bearing belt and was probably inhabited by people involved in salt production, a similarly large proportion of bottoms with feet (37.38 %) was found. The same can be said about the sediments in Podłęże 1[85] or in Kraków-Mogiła 62[86]. This may indicate that the feet were removed as unnecessary ballast at the first, local area of salt distribution, or that the last stage of production (drying and portioning) was performed at the above-mentioned sites around the salt-bearing belt (see chapter 4.1).

3.2.5 Disposal of ceramic waste

The problem of the disposal and storage of ceramic waste from salt production in the Kraków-Wieliczka region has not yet been subjected to in-depth research. This is partly due to the fact that the scale of the phenomenon and the problem of waste deposition in sediments have only been highlighted by large-scale excavations related to the construction of the A4 motorway. The number of fragments revealed in their course ranged from several to several thousand, up to about two million fragments (Kraków-Bieżanów 11). Earlier studies included series smaller by orders of magnitude[87]. The presence of depressions or pits filled almost exclusively with briquetage debris, previously only mentioned in the literature, has been confirmed in new studies on a number of sites with a full production cycle, i. e. with traces of mass brine evaporation (those where salt-making ceramics constituted more than 30 % of the collection) (e. g. Kraków-Bieżanów 11, 15; Kraków-Kurdwanów 12; Brzezie 17; Wieliczka 112; Zakrzów 1). An example of the described practices of deposition of post-production ceramic rubbish is the object 411 registered at site 11 in Kraków-Bieżanów (Fig. 25). This irregular feature, measuring 750×300 cm, with a thickness of approx. 170 cm, was filled with functional and run-off layers and ceramic debris of various degrees of fragmentation (from loose ceramic fines to several centimetre-long identifiable fragments of Form 2a vessels). As there is a furnace in the immediate vicinity of this object (see chapter 3.2.2) – object 320 (Fig. 24), it seems that there is no doubt as to the interpretation of this structure as accompanying waste pit. Such depressions into which the remains of broken/used salt cups were thrown are recorded at this site several more times, although on a smaller scale. Examples of similar landfills are known from other sites where traces of salt production have been noted – for instance, from France[88]. On the other hand, at the sites with only the drying and portioning stage confirmed, this type of mass stratification was not confirmed (e. g. Podłęże 17).

The use of ceramic debris on the sediment from the early phase of the Late Bronze Age (Ha A) in Brzezie 17 is noteworthy. Probably there were full *chaîne opératoires* on site, from clay extraction to briquetage production and initial brine evaporation in Form 1b bowls. The latter step was most likely performed at periodic springs of salt water, on the outskirts of the settlement (Fig. 23). The portioning itself in the Form 2a cups took place also (or maybe only?) in

80 Ibid. 2015, 122–129.

81 Difficulties with extracting the briquette of salt as an intact entirety from Form 2b cups are confirmed, among others, by experiments carried out by employees of the Cracow Saltworks Museum in Wieliczka (kind information from J. Fraś).

82 See Jodłowski 1976, 156; Matoga 2017, 146.

83 Kadrow 2003, 217.

84 The overrepresentation can be explained in part by the greatest thickness of the bottom part, and thus a greater chance of this part of the vessel surviving. On the other hand, this tendency should be balanced by the fact that the feet usually remain as a single piece, while the tall, thin-walled upper part breaks down into many fragments (in statistically relevant collections of ordinary kitchen pottery, the proportion of bottom fragments to all shards of pottery should be approx. 3–7 %; cf. Bazielich 1993, fig. 11; Kuna 2012, tab. 41a; Dzięgielewski 2013, 42).

85 Rydzewski 1989.

86 Bazielich 1993.

87 Cf. Jodłowski 1971; Fraś/Kolebuk 2019; 2021.

88 Cf. Olivier/Kovacik 2006.

Fig. 25: Kraków-Bieżanów, site 11. Cross-section of a disposal pit for post-production ceramic debris from (feature 411). Photo by M. Materna.

the aboveground furnaces located within the homesteads, as evidenced by the uniform distribution of specially designed pads (Form 3a) (Fig. 23). In the central part of the settlement, at a distance of about 200 m from the supposed salt springs, relics of a road stretching along the NS axis were discovered, which along the section of approx. 31 m long, as a result of long-term use as a communication route, was deepened due to erosion, creating an indentation (erosional valley) surviving in the form of a series of parallel ruts, intentionally filled with fragmented ceramic material, almost entirely derived from the briquetage (Fig. 26). There is no reason to combine this route with any extensive organised system of salt-making – for example, brine delivery or collection of the finished product. It was probably the usual internal road within the estate, which was paved with briquetage from the nearby heaps of ceramic waste from earlier or contemporaneous salt production (mostly broken Form 2a cups). This is evidenced by the fact that the homesteads adjacent to this structure bore traces of regular sedimentary activity: there were storage pits (cellars), post-build buildings, a weaving workshop, etc. Therefore, salt making was an important, but not the only, activity undertaken by the inhabitants, probably of a seasonal nature. It is the only evidence of utilitarian use of ceramic waste from salt production in the region so far.

4 Distribution, manufacturing specialisation and social role of salt

4.1 Distribution in containers

As shown above, the distribution of the salt in the pottery packages must have only taken place over short distances and solely when using the younger, lighter Form 2b chalice cups. As the comparisons of the macroscopic patterns of ceramic technology have shown, the production of these cups, even those found in sites ascertained to have only been involved in the final stage of *chaîne opératoire* (salt drying and portioning), only occurred in settlements with an initial or full salt production cycle. Only at these sites have clay pits been proven to have existed. Such a conclusion is also supported by the observation from Podłęże 17, where the salt cups (Form 2b) are the only group of pottery with sand as a dominant temper of the ceramic paste. Sand was not available here (see chapter 3.1.2.2; Fig. 11,c). The cups were found here mainly (almost 40 % of cases) in the form of bases with a foot. This means that from the brine evaporation sites (with initial evaporation) the salt was brought here either together with the portioning vessel (in the form of a ready-made product with packaging), or as an intermediate (salt molasses) together with bare containers, or even as clay matrix tempered with sand, prepared in the same place where the molasses (on the 'sandy' sites). Here

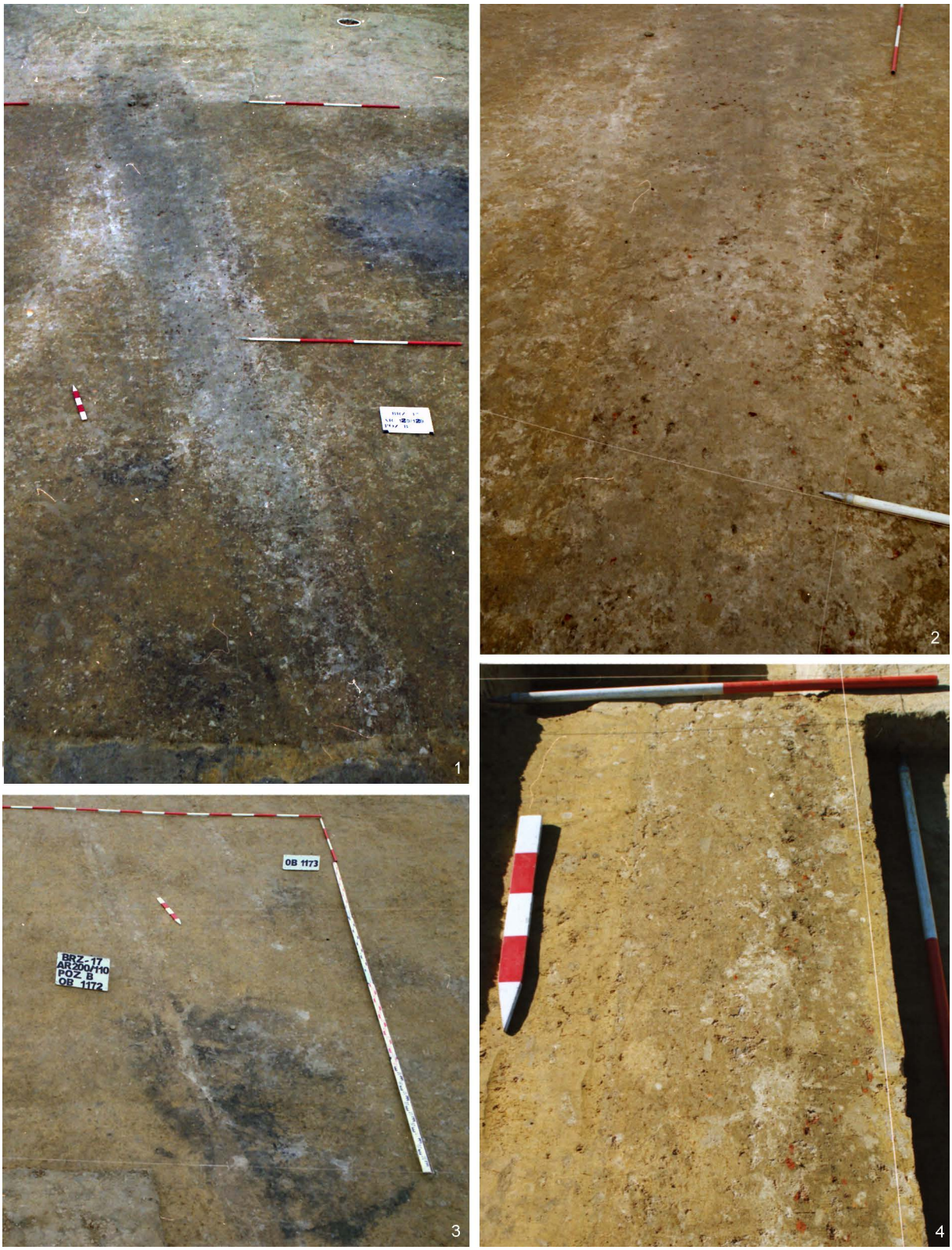

Fig. 26: Brzezie, site 17. Plan views of Bronze Age road (beaten tract) with ruts and fill partially 'paved' with briquetage debris. Photos by A. Czekaj-Zastawny, A. Zastawny.

in Podłęże, on the outskirts of the salt-bearing belt, Form 2b cups were brought or made from this matrix to carry out the final drying of the brine and portioning of salt. It cannot be ruled out that in the Early Iron Age, when the Podłęże 17 site was inhabited, both of these activities must have taken place in the settlements surrounding the salt-bearing belt, due to the already significant deforestation in the heart of this belt, which had been continuously exploited in this way since the early Bronze Age[89], and due to resulting firewood shortage. In order to confirm one of the above assumptions, it would be necessary to track the form in which the fragments of the briquetage are found at sites located outside the salt-bearing belt. A similar picture (predominance of feet) is shown by materials from a slightly older settlement in Podłęże 1[90]. At the settlement in Kraków-Mogiła 62, on the left bank of the Vistula River, approx. 8–9 km from Kraków-Bieżanów and Wieliczka, there were equally numerous feet[91], and it was the same with the settlement in the abbey in Kraków-Tyniec 2[92]. There are more than 20 sites located less than 10 km from the salt-bearing belt where Form 2b cups, mainly the feet, were found (Fig. 27). Characteristic supports of Form 2b revealed slightly further from the Kraków-Wieliczka salt-making centre come from Dobczyce (about 10 km to the S[93]), Ojców-Zamek (approx. 25 km to the N[94]), Witów (about 35 km E[95]), and also from Zabrzeż (50 km to the S[96]) and Stary Sącz (about 65 km to the SE[97]) in the Carpathians. At other sites in Małopolska, incidentally some fragments of the walls of the 2b cups have been identified – for example, at Warzyn Pierwszy 7 (approx. 80 km to the N[98]), albeit virtually without characteristic feet[99]. Therefore, it can be assumed that the separation of the bottom parts from the Form 2b cups, if it was made to facilitate transport, did not take place immediately at the drying and portioning site, but on the sediments around the salt-bearing belt (within a radius of approx. 10 km) inhabited by people involved in the extraction and evaporation of brine and production of salt by thermal condensation. The first of these activities took place directly within the salt-bearing belt (Fig. 27; e. g. in Biskupice 1, Brzezie 17, Kraków-Barycz 5, Kraków-Bieżanów 8, 11, 15, 20, 27, Kraków-Kurdwanów 12, Wieliczka 112, Zakrzów 1), occasionally outside this strip – for instance, at the site located on the left bank of the Vistula, in Kraków-Cło, where single Form 1b bowls and Form 3 pads were found[100]. The latter find confirms the occasional transport of concentrated brine outside the salt belt, probably as a result of individual actions of the inhabitants of the settlement, perhaps aimed at meeting immediate needs. On the other hand, the second stage, involving drying and portioning, took place in the same sediments, as well as in other, 'ordinary' dwelling zones in close proximity to the salt zone (Fig. 27; e. g. in Kokotów 19, Kraków-Bieżanów 21, 30 and 33, Kraków-Mogiła 1 and 62, Kraków-Tyniec 2, Podłęże 1 and 17, Zakrzów 2, 13 and 28). Only at these settlements were the feet (or the entire containers) possibly removed in order to facilitate transportation over longer distances. The nature of the remaining sites with the relics of briquetage (Fig. 27) is difficult to determine due to the state of their research or the negligible amount of salt-making pottery.

4.2 Other indicators of distribution and the evidence of long-distance exchange

Containers were transported over relatively short distances. However, there is no direct possibility of confirming the distribution of salt without containers. One of the indirect ways of inferring more distant distribution is the emergence of standard measures for this raw material, which for the region in question has been confirmed since the beginning of the Late Bronze Age (see Chapt. 3.2.3). Another indication of a long-distance salt exchange may be the appearance of symptoms of social differentiation or an increase in the wealth of the community involved in salt production. The emergence of a social group controlling the exploitation of a scarce resource is particularly likely when access to this resource may be controlled. A classic example is the Alpine salt mines from the Early Iron Age[101], with their rich cemeteries in Hallstatt[102] or Dürrnberg bei Hallein[103]. In the case of the Kraków-Wieliczka salt-bearing area, such manifesta-

89 Dzięgielewski *et al.* 2024b.
90 Rydzewski 1989.
91 Bazielich 1993.
92 Jodłowski 1971, 193; Dymek 2002.
93 Jodłowski 1971, 176.
94 Kot *et al.* 2021, 219–220.
95 Oral inf. A. Gawlik.
96 Jędrysik *et al.* 2021, 454 pl. 4,gg, 8,o. It cannot be ruled out, however, that the cups found here may have come from local, as yet unknown salt production, rather than 'imported' from the Kraków-Wieliczka region.
97 Jodłowski 1988, 11.
98 Łaczek/Przybyła 2013, 26 tab. VIII,q.
99 Identification of a single characteristic fragment of briquetage in the material from this settlement should probably be owed to the presence in the research team of a person who knew such materials from Kraków from the autopsy. The circumstances of identifying the fragments from Witów and Zabrzeż are similar. It can therefore be assumed that similar evidence from other sites from Małopolska have not been correctly interpreted so far.

100 Wójcik 2020, 312–313 fig. 3,1–3.
101 Reschreiter *et al.* 2009; Kowarik/Reschreiter 2010.
102 Kromer 1959.
103 Wendling 2020.

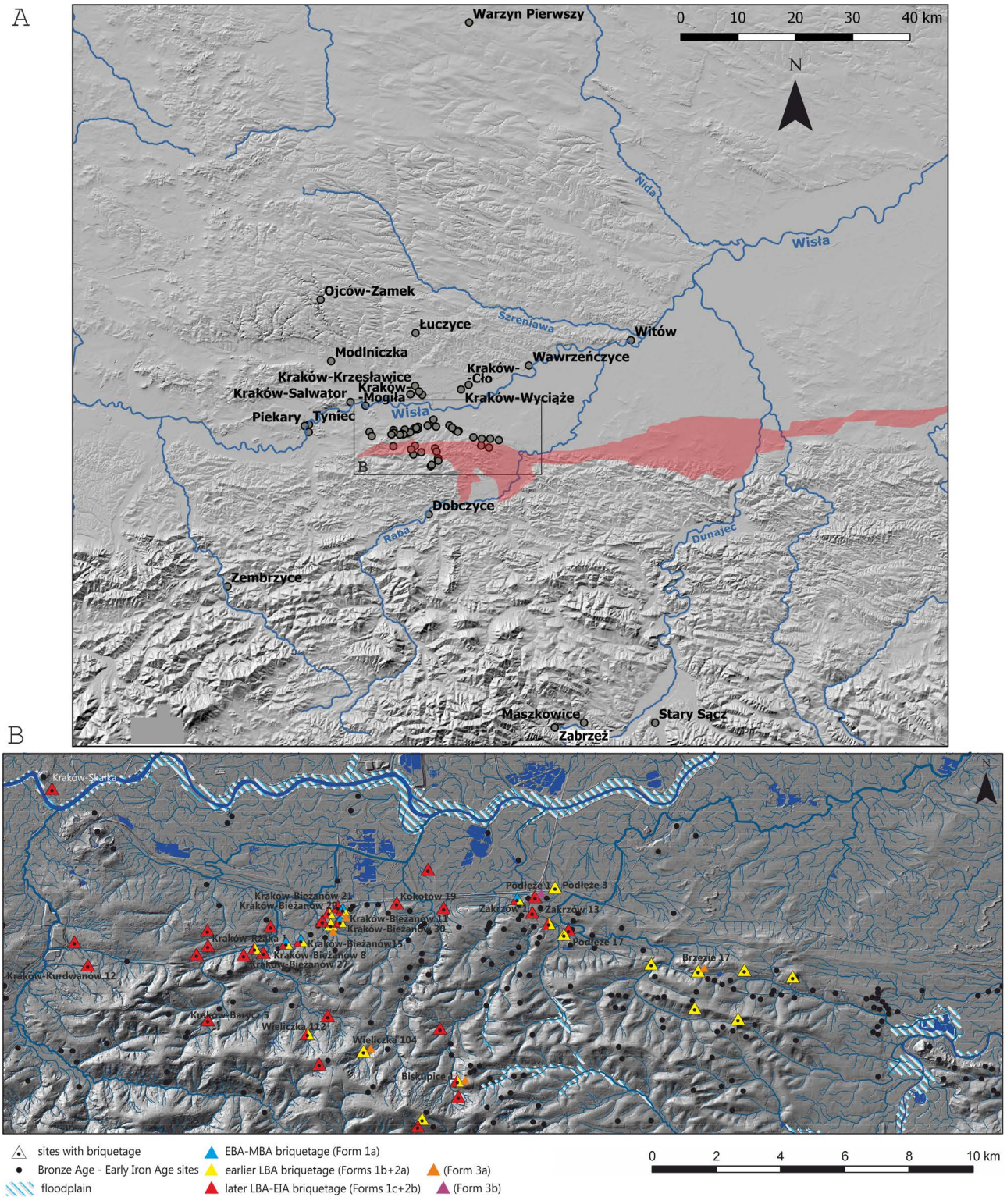

Fig. 27: Distribution of Bronze and Early Iron Age briquetage sites across western Lesser Poland (A, evaporites of the Zgłobice Unit marked light red) and location of the main salt-making sites in Kraków-Wieliczka area mentioned in the text against the background of the settlement network (B).

tions of social differentiation are clearly lacking. Analyses made on the basis of archaeological indicators of 'wealth' for large urnfield cemeteries located in this region and its immediate hinterland (Targowisko, Kraków-Prokocim, Kokotów), show a trend from quite extreme differentiation in the early Late Bronze Age (Targowisko: Gini coefficient 0.76)[104], when we note for the first time the 'unit' of salt in the form of a fairly standard briquette (Form 2a), to relatively high egalitarianism at the end of the Late Bronze Age and the beginning of the Iron Age, when there were biritual necropolises with a local style of material culture (the Upper Silesia-Lesser Poland group of the Lusatian culture) (Kraków-Prokocim, Kokotów with Gini coefficient: 0.45 and 0.55, respectively[105]). This younger, egalitarian state corresponds to the époque when the smaller salt-making cups (Forms 2b) were in use. However, a small degree of differentiation in the symptoms of wealth is also characteristic of other contemporary cemeteries in Upper Silesia and Lesser Poland[106].

On the other hand, when considering the qualitative criteria, the analysed cemeteries (similarly to the settlements) do not show any accumulation of 'prestigious', i. e. rare, imported or labour-consuming objects. It is also difficult to show traces of a diversified spatial organisation based on the criterion of 'affluence' (size or quality/technical differentiation of the forms of homesteads, houses or storage pits) in the dwelling areas in the salt-bearing belt near Krakow[107]. There is also scant evidence that the settlements in this area were fortified, which could be interpreted in terms of an attempt to limit access to rare raw materials or to protect the status acquired thanks to their exploitation. Small palisade fences, registered at several sites (Kraków-Bieżanów 15[108]; Podłęże 17[109]), seem to have performed a purely economic (agricultural) function (barracks for animals, kraals?), as indicated by their small size and lack of traces of distinctive households or homesteads within them. In circumstances of social organisation characteristic of the communities of interest here – segmental, poorly hierarchical, or to minimal degree ranked village communities[110] – it was not possible to exercise control over exploitation of the raw material in the form of salty springs, characterised by egalitarian 'open' access. This hampered the described communities from fortifying settlements that tended to be built where resources or profits obtained from them were easy to protect by a defensive form of settlement[111].

The attractiveness and availability of a given resource can also be verified by tracing the presence of diverse cultural traditions in a given territory. The areas near Kraków, including the fertile loess on the left bank of the Vistula[112] and loess-like soils on the right bank of this river[113], from the beginning of the Neolithic (and even earlier) attracted various population groups, including representatives of the first and second waves of early agricultural Danubian cultures[114], the Baden culture[115], and the Corded Ware culture[116]. This trend to attract new groups of settlers also continued in the Bronze Age[117] and later, in the era of Celtic or Carpatho-Dacian settlement[118]. Only recent large-scale excavation related to the construction of the A4 motorway, crossing the salt belt, clearly highlighted and confirmed the validity of the hypothesis which had been so timidly expressed so far, that one of the reasons for the attractiveness of the area near Krakow was salt[119]. And so, the agricultural communities typical of the Trzciniec culture from the Middle Bronze Age (16th–14th century BC), whose regular southern range was marked by the edge of the loess terrace on the northern, left bank of the Vistula[120], established only specialised production sites in the salt-bearing right bank of this river (Kraków-Bieżanów 15, Zakrzów 1[121]). Despite extensive excavation research, we do not know of any other settlements here that would prove a stable, agricultural settlement[122], unlike the left, loess bank of the Vistula.

The region near Kraków also provided several clear examples of prehistoric migrations of human groups from greater distances, probably induced by interest in salt. At the beginning of the Late Bronze Age, in the Br D phase (14th–13th century BC), when the pattern of the Lusatian culture was only just stabilising in the Odra basin, which was part of the socio-economic model of the Central European communities of Urnfield cultures, some groups of people migrated from the Oder River, from the area of

104 For earlier periods of the Bronze Age, we do not have necropolises within the salt-bearing area in the Kraków region.

105 Research based on Jørgensen's 'scarcity coefficient'; for methodological explanation see Dzięgielewski *et al.* 2024c.

106 Cf. Przybyła 2013, 219.

107 Dzięgielewski *et al.* 2024c.

108 Przybyła M. M. 2017, fig. 11.

109 Dzięgielewski *et al.* 2024a.

110 See Przybyła 2013; Przybyła M. S. 2017; Kienlin 2013; Dzięgielewski *et al.* 2024c.

111 Dzięgielewski 2017.

112 Cf. Tunia 1997.

113 Cf. Naglik 2005; Chochorowski/Drobniewicz 2008; Kadrow 2018.

114 Czekaj-Zastawny 2008; Nowak *et al.* 2007.

115 Zastawny 2015.

116 Włodarczak 2020, 46.

117 Przybyła M. S. 2017.

118 Dulęba 2009; Bochnak/Dzięgielewski 2020; Madyda-Legutko 1994.

119 Przybyła 2015; Przybyła M. M. 2017; Bochnak/Dzięgielewski 2020.

120 Górski 2007.

121 Przybyła 2010; 2015.

122 Przybyła 2010; Czerniak *et al.* 2018; Mazur/Dzięgielewski 2024.

Upper Silesia (approx. 150 km west of today's Kraków). Until recently, this phenomenon was discovered mainly thanks to research on the left-bank loess terrace of the Vistula in the area of Kraków-Nowa Huta[123]; therefore, the agricultural potential of fertile soils developed on loess was determined to be the main 'pull-factor' of this migration. Today we know that it was not the only possible stimulus for the arrival of this population, because, inter alia, the research presented here confirmed the traces of salt exploitation by representatives of the early Lusatian culture community. A little later, in Ha A (12th century BC) in this region of Małopolska, as in other places along the Carpathian arc, groups of people of Transcarpathian roots also appeared, using characteristic Belegiš II-style ceramics[124]. In Brzezie 17, both population groups (with the Silesian and Transcarpathian traditions initially clear-cut in ceramics) jointly used the space of the settlement and dealt with salt-making[125]. In Ha A1 (or in Br D) there was probably a qualitative change in the organisation of salt production, visible from the appearance of a metric standard (Form 2a cups). At the same time, approximately in the 11th century BC, in the younger part of the Late Bronze Age (from Ha B), a local cultural group was formed in this area, with a less syncretic, specific face of material culture (Upper Silesia and Lesser Poland group[126]). There was still evidence of long-distance contacts, mainly with the Carpathian zone[127], and on the threshold of the Early Iron Age, the impacts of the early Eastern Hallstatt centres from the south and west[128] and the steppe zone from the east[129]. However, these are not testimonials allowing one to speak of mass migrations of human groups, as in the beginning of the Late Bronze Age.

Another wave of settlers whose appearance in the area near Kraków could be related to the presence of salt deposits were groups of Celtic settlers who probably came from the area of Moravia or Upper Silesia in the 1st half of the 3rd century BC[130]. For this period, however, we do not have as much data on the organisation of salt-making as for the Bronze Age, which is certainly due to the lack of specific vessels related to this production[131]. In conclusion, it can be stated that the cyclical appearance of population groups of various provenance in the Kraków-Wieliczka region, with no traces of conflict situations, should be considered as another confirmation of the availability of the resource in form of the salt springs.

4.3 The issue of salt-making as craft specialisation

In this subchapter, we would like to refer to the suggestions appearing in older literature that salt-making of the Bronze Age and the Early Iron Age in Małopolska was an activity requiring craft specialisation[132] or even an influx of foreign specialists[133]. This issue requires clarification of the very concept of 'productive specialisation' in prehistoric societies. Contrary to the arbitrary judgments sometimes present in the archaeological literature, based, for example, only on the technological advancement of a given branch of production (the further the advancement, the greater the probability of the existence of specialists), anthropological studies pay attention to the fact that in pre-modern societies with generalised exchange, specialisation tended to manifest itself in the form of a fluent professionalisation range within a continuum between the pure *domestic mode of production* and the developed *craft specialization*[134]. A distinction must also be made between 'site specialisation' and 'producer specialisation'. The presence of sites with various functions, already characteristic of hunter-gatherer communities[135], does not necessarily mean the presence of specialist craftsmen. A typical illustration of this distinction are, in our case, 'monofunctional' salt-making sites from the Early and Middle Bronze Ages, undoubtedly used on an ad hoc basis (seasonally?) by the residents of regular settlements on both sides of the Vistula river (in the case of the Mierzanowice culture) or only on its left bank (in the case of the Trzciniec culture). Referring to the definition of specialisation proposed by C. L. Costin[136], we do not believe that their users could have produced salt on the basis of 'regular, repeated provision of some commodity or service in exchange for some other'. Suggesting craft specialisation towards users of these sites is not confirmed either by the relatively small volume of production[137] or by the technological or organi-

123 Górski 2010.
124 Przybyła 2009.
125 Dzięgielewski 2012b; Przybyła M. S. 2017.
126 Durczewski 1946; Gedl 1982; Dzięgielewski 2024.
127 Przybyła M. S. 2017.
128 Dzięgielewski *et al.* 2020.
129 Dzięgielewski 2024.
130 Dulęba 2009; Dzięgielewski 2016; Bochnak/Dzięgielewski 2020.
131 Cf. Jodłowski 1976.
132 Jodłowski 1976, 168; 1988, 136.
133 Bukowski 1988, 124.
134 Costin 1991.
135 Cf. Binford 1980.
136 Costin 1991, 3.
137 In Kraków-Bieżanów 15, approximately 140,000 fragments of ceramics (briquetage) and about 150 sunken hearths was spread over almost 8 hectares, used for at least several to several dozen years in the Middle Bronze Age.

sational side of this process (e. g. no stage of salt portioning in containers). A more comprehensive system of organisation of brine evaporation and salt packaging appears at the beginning of the Late Bronze Age with the first salt portioning containers (Form 2a cups), but then – just like until the end of the time period analysed here – there are no monofunctional sites. On the contrary, we have a lot of evidence of the functioning of both stages of production (1st stage: brine concentration, and 2nd: batching) in many sites and in different parts of them (sometimes slightly more concentrated, sometimes completely dispersed among households). At the same time, the emergence of the need to standardise the form of the briquette confirms an increase in external demand, which could have probably only been satisfied by enhancing the degree of specialisation of some members of Late Bronze Age community. The assumption of the seasonality of production – i. e., its highest intensity in the summer season, which is also the most loaded with field work[138] – on the one hand, forces us to assume that the mentioned part of the population had to be somehow released from the need to fully participate in the supply of agricultural products, but on the other hand, it suggests that it could not have been full-time production, which might be allowed, for example, in the case of metallurgical activities, which could have been enforced all year round.

The argument of yet another kind against full or even half-full manufacturing specialisation (about half of the time allocated to a given activity by selected entities) emerged as a result of analyses conducted as part of the project 'Inheritance, social network or local adaptation? Bronze and Early Iron Age societies in western Małopolska'[139]. The mapping of traces of salt-making from the Late Bronze Age and the Early Iron Age against the background of soil maps of the region revealed that the material status of the population, as evidenced in the standard of grave furnishings, depended primarily on the agricultural potential of the soil, and not on the local availability of salty springs (although the greatest inequalities was found in the cemetery in Targowisko, where there were probably two favourable economic factors: fertile soils developed on loess and access to brines). This means that for the majority of society, agriculture remained the primary means of supplying food, regardless of the potential or actual exploitation and exchange of a rare resource, which was salt. It would be exaggerated to say, however, that there was no degree of specialisation in the field of salt acquisition, in other words that it resembled the model used in traditional village community of contemporary Romania and Moldova, where until recently the representatives of every separate farm have been involved in ad hoc mining and processing of brine for their own needs[140]. In our opinion, traces of routinised activity (specialised hearths, standard containers) prove the presence of some 'specialists', organisers of periodically practiced production. An analogy can be drawn here from the small-scale agricultural segmental society of Baruya from the Eastern Highlands of New Guinea[141], where the general preparations for seasonal salt extraction (e. g. wood harvesting) were undertaken by larger, gender diverse groups, sometimes constituting more than half of the village community. The direct extraction (crystallisation and portioning) of this mineral was done – of course not continuously – by a much smaller group, composed only of men and consisting of about 5–15 % of the village population. However, they were not people to whom we would assign the role of 'craftsmen', but rather 'specialists', 'insiders', who were also engaged in other economic activities. The arguments presented above in favour of a moderate range of manufacturing specialisation among the Małopolska communities in the late prehistory, seem to correspond to this model.

5 Recapitulation

The two *chaînes opératoires* associated with making salt in ceramic vessels – the pottery making and the brine saturation, salt crystallisation, and forming a transportable commodity (salt cakes) – can only be separated to a certain extent and at certain stages of production, i. e. in the initial and final stages (Fig. 28). Thanks to the considerable progress in terms of fieldwork and experiments in recent years, we are able to demonstrate the presence and course of the particular stages on many sites in Kraków region. However, only a few of them (like Brzezie 17 or Kraków-Bieżanów 11) show traces of full operational sequences.

Reconstruction of the organisation of salt production in the salt-making centre near Kraków shows that four types of sites related to salt exploitation can be distinguished: (1) production sites, devoid of stationary structures and movable materials that could indicate regular habitation, (2) residential settlements with a separate salt-making part, (3) settlements with scattered traces of salt-making activity within the inhabited part, (4) non-productive estates, with traces of the final stages of the process of evaporation, bri-

138 Dzięgielewski *et al.* 2024c.
139 Przybyła *et al.* 2024.
140 Chiricescu 2013, 275–280.
141 Godelier 1969.

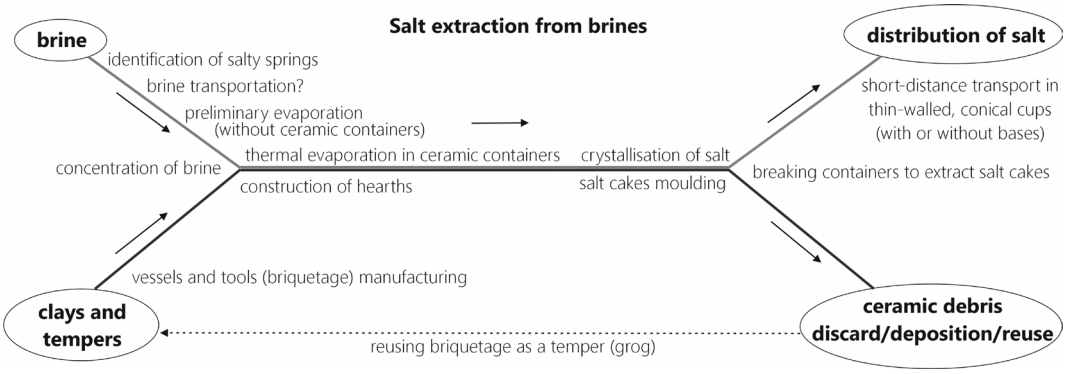

Fig. 28: Scheme of the intertwined chaînes opératoires in the production of salt from brine using ceramic vessels.

quette formation or salt packaging. The location of each type is closely related to the distribution of saltwater resources. Some sites, from the Early and Middle Bronze Age (e. g. Kraków-Bieżanów 15) or from the Early Iron Age (e. g. Kraków-Barycz 5), were strictly production sites. In others, this activity was concentrated in specific zones, especially in low-lying areas with access to salt springs (e. g. Kraków-Bieżanów 11). There are also other patterns of distribution of traces of production – without spatial separation from the residential part of the settlement (e. g. in Brzezie 17), as well as evidence of the completion of the final stages of production (forming salt cakes or separating them from containers) in essentially non-productive settlements (e. g. Podłęże 17; Kraków-Cło 65). Apparently, some sites outside the salt-bearing zone were functioning in the system just as dwelling places of the salt-makers, or as places intermediating in long-distance distribution.

None of these sites can be compared, in terms of quantities of the briquetage, with the 'industrial' centres of the west European Iron Age[142]. Given that our analysis also suggests that we cannot speak of full craft specialisation of salt-making in the Bronze Age and Early Iron Age in southern Poland, it is reasonable to conclude that the apparent heterogeneity of the salt-making sites of the time in Małopolska stems from the fact that the production was mostly spontaneous and organised from the bottom up, if not 'domestic' in some periods. It was performed by segmented societies without distinct hierarchies, which did not monopolise access to this rare resource. At the same time, they performed some forms of medium- and long-distance exchange of a high-value commodity, but the range of influence of this activity is currently hard to estimate[143]. It seems plausible that at the turn of the Bronze and Early Iron Ages it overlapped at least with the range of other uniform culture traits proving mutual contacts, like pottery style, costume, or burial custom (biritual burials), stretching to today Upper Silesia, Lesser Poland and the western Carpathians.

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