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'Whitestone'—A Specific Polished Stone Tool Raw Material in the Late Neolithic of Southern Hungary

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Abstract: 'Whitestone' is a characteristic raw material in the Late Neolithic (Tisza and Lengyel culture) polished stone tool (chisel, adze, macehead) archaeological record in Southern Hungary. However, the lithology—the technical term not reflecting a petrographic definition—needs detailed petrographic-analytical investigations (by optical microscopy, PGAA, and SEM-EDS) to determine the exact rock types and to connect them to specific geological sources. This article identifies the main types of 'whitestone' and, furthermore, focuses on the predominant 'silicified magnesite' type and the secondary 'silicified limestone/dolomite' type. Based on our results, both types originated from the alteration of serpentinized ultramafic assemblages, most probably from the closest magnesitic alteration zones of serpentinite outcrops in Serbia. Thus, the most possible provenance of the Late Neolithic 'whitestone' polished stone tools is the Serbian magnesite. These lithologies are in the territory of the Late Neolithic Vinča culture, which was engaged in mass production of 'whitestone' tools. This fact indicates the strong relationship of that population with the Tisza and Lengyel communities.

Keywords: polished stone tool; adze; chisel; macehead; magnesite; dolomite; limestone; serpentinite; original surface SEM-EDS; PGAA

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1. Introduction

The topic of this study is a specific raw material employed for polished stone tools, called 'whitestone', which is a technical term and does not reflect a petrographic definition. This group of raw material was first described from Bosnia and Herzegovina in the Butmir culture [1–3] and from Serbia in the Late Vinča culture [4]. In modern archaeological research, Dragana Antonović [4] used this technical term for all light-colored, lightweight rock types applied for mass production of tools from the Late Neolithic till the Copper Age, mostly related to the Late Vinča culture (the entire Vinča culture is dated to 5155/5105-5040/5000 BCE, while its late period involves the Vinča C (5040/5000–4725/4695 BCE) and Vinča D (4725/4695–4710/4655 BCE) on the territory of present-day Serbia, and the

Butmir culture (5100 to 4500 BCE) in Bosnia and Herzegovina [4–12]. 'Whitestone' has a greyish white to yellowish white hue, is very fine-grained, micro- to cryptocrystalline, and is a porous lithotype with variable hardness from the dusty one to the compact one with a conchoidal fracture [6].

'Whitestone' as the raw material used for making polished stone tools has always been discovered in association with Tisza and Lengyel cultures in the Southern Great Hungarian Plain and Southern Transdanubia in the territory of present-day Hungary. The Tisza culture dates back to the Late Neolithic, 5000–4500 BCE, across the entire Great Hungarian Plain; however, it is strongly related to the Tisza River and its smaller tributaries [13–17]. The Lengyel culture (Lengyel I-II) is dated to the Late Neolithic period of 4900–4500 BCE in Transdanubia [15,18–20].

The vast majority of the sites were excavated in the 20th century and published entirely or in part, including Hódmezővásárhely-Gorzsa-Czukor-major, Tápé-Lebő Alsóhalom, Lengyel-Sánc, and Zengővárkony-Igaz-dűlő (Figure 1) [21–30]. The Alsónyék-Bátaszék site was uncovered in the 2000s and offered a comprehensive cross-section of the entire Neolithic period [19,31]. These sites provided significant quantities of 'whitestone' tools, which constitute the fundamental research material of this study. The common tool types include flat chisels and adzes, shoe-last (shaped) adze, and maceheads (Figure 2) [28,29,32]. In many cases, these tools were found in burial contexts, though domestic contexts were observed as well. The archaeological literature mentions these tools with variable material names from travertine [28] through chalk, fine crystalline dolomite, calcareous chert, cherty magnesite, limnoquartzite, and chert in general to magnesitic sandstone and magnesitic serpentinite [33].

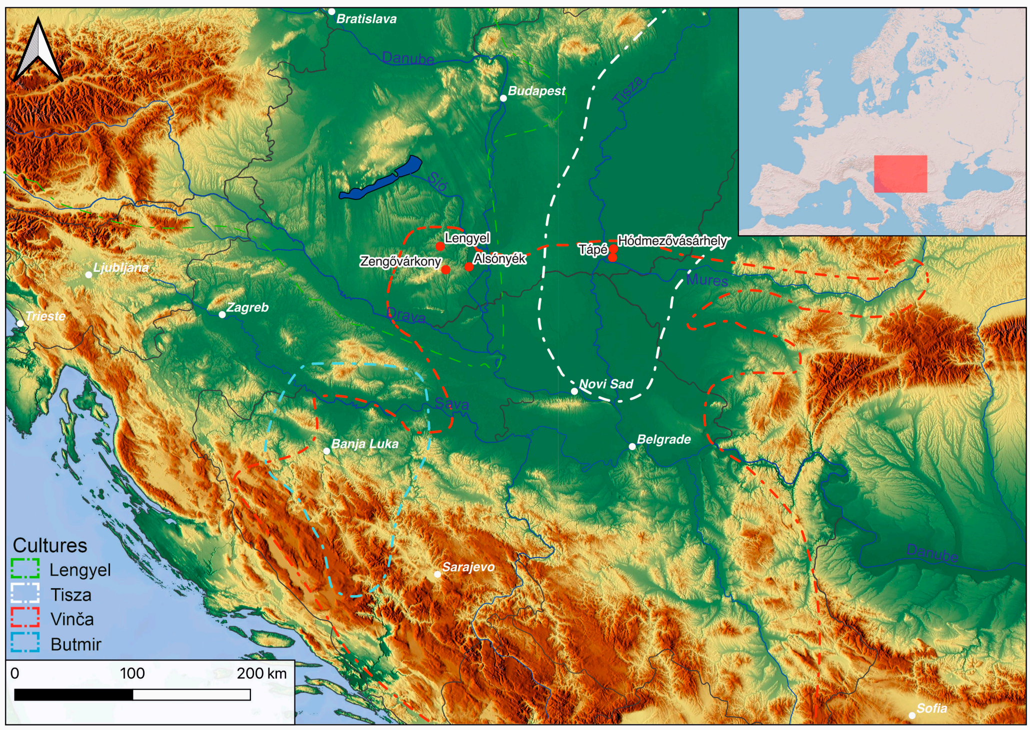

Figure 1. The location of archaeological sites (red dots) from which instrumentally investigated 'whitestone' polished stone tools were discovered. Geographic distribution of Late Neolithic archaeological cultures (Lengyel, Tisza, Vinča, and Butmir) mentioned in the text are indicated with dotted lines. The maps are provided by https://maps-for-free.com/layer/relief/z%7Bz%7D/row%7By%7D/%7Bz%7D_%7Bx%7D-%7By%7D.jpg, accessed on 6 March 2025. The projection is in EPSG:23700; HD72/EOV for the maps. Map made by Kata Furholt.

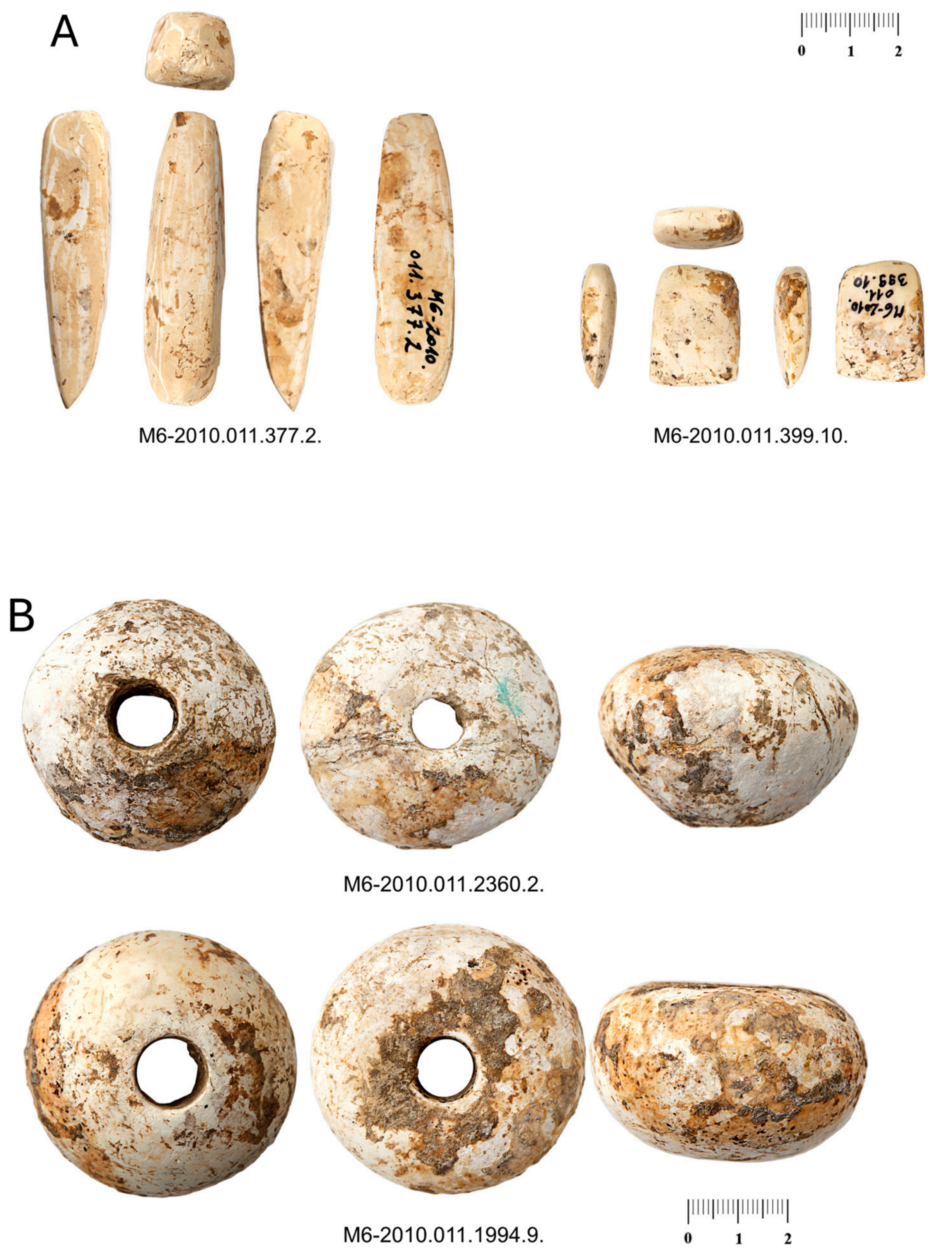

Figure 2. 'Whitestone' polished stone tools: (**A**) shoe-last (shaped) adze, flat chisel and (**B**) maceheads from Alsónyék-Bátaszék (photo: K. Furholt). All artefacts were discovered from burials as grave goods.

Previous petroarchaeological studies [6,33–36] have shown that 'whitestone' may be attributed to different lithologies: cherty magnesite, limestone, diatomite, tuff-tuffite, porcellanite, and even lithified bone. Our aim is to characterize the types of 'whitestone' by petro-mineralogical and geochemical methods based on the Late Neolithic archaeological record of Southern Hungary. In addition, our attention focused on the predominant raw material type, which has a siliceous–carbonaceous composition and contains carbonates (magnesite, dolomite, and calcite) as the most common mineral phases. A possible provenance is proposed for this 'whitestone' type.

2. Materials and Methods

There are 234 archaeological polished stone tools identified as 'whitestone' from five localities in Southern Hungary (see the list in Supplementary Materials Table S1 and Figure 1). Two sites are located in the Great Hungarian Plain and are connected to the Late Neolithic Tisza culture: Hódmezővásárhely-Gorzsa-Czukor major and Tápé-Lebő

Alsóhalom. Three sites can be attributed to the Late Neolithic Lengyel culture in Southern Transdanubia: Alsónyék-Bátaszék, Lengyel-Sánc, and Zengővárkony-Igaz-dűlő.

Research on the Lengyel culture first began in Southeastern Transdanubia at the end of the 19th century. Between 1882 and 1888, Mór Wosinsky carried out excavations near the village of Lengyel ("Töröksánc") in Tolna County, which later became the name of the entire newly discovered and separate cultural unit. Wosinsky described and analyzed in detail the excavated settlement, the burial customs, and the individual types of finds, paying special attention to examining the production technique of the objects (e.g., polished antler tools and jewelry made of shells [27,28]). However, no detailed photographs or excavation drawings were made during the excavations carried out at the time, and only a small part of the finds were published [25,26,37]. Wosinsky excavated two groups of graves in Lengyel: the "eastern group" contained 80 graves, and the "southeastern group" had 47 burials [38] (p. 55). T. Biró et al. [39] presented a short summary (poster) on the comprehensive study on the remnants of the polished stone tool assemblage, mentioning 'whitestone' as a characteristic component of the archaeological record.

The Zengővárkony-Igaz-dűlő site is located in Baranya County, at the foot of the Mecsek Mountains. János Dombay excavated the site from 1936 to 1948. Among the settlement features and buildings, 379 burials from 368 graves were found in small and large grave groups [29,30,38,40]. A timber-framed building, the numerous excavated features, and the many burials found made it the largest known site of the period. Recent aerial photography and geomagnetic surveys suggest that the site covers an area of 40 ha [41] (p. 82) and reveal the presence of a double circular enclosure [42]. Polished stone tools from Zengővárkony were originally studied by Zsolt Schléder and his colleagues [35]. Archaeological and petrographic descriptions together with dimensional data are applied in this study from their publication for revision.

The Alsónyék-Bátaszék site is located in the southern part of Tolna County, northwest of the town of Bátaszék, at the border between the Transdanubian Hills and the Great Hungarian Plain. It is bordered by the Szekszárd Hills to the west and by the wide floodplain of the former courses of the Danube to the east. It was excavated between 2006 and 2009 during the construction of the M6 motorway [31]. The excavated area covers about 25 hectares and brought to light about 15,000 archaeological features spanning almost the entire 6th millennium and the first and second thirds of the 5th millennium cal BCE (Starčevo, LBK, Sopot, and Lengyel cultures) [31,43]. The settlement reached its greatest extent in the Late Neolithic during the Lengyel period (ca. 4800–4400 cal BCE), with about 2300 burials, 122 buildings, and many pits. Archaeological interpretation of the phenomena and finds is part of ongoing interdisciplinary research projects. First results on the archaeometric study of the polished stone tool assemblage were presented by Szakmány and his colleagues [44].

Hódmezővásárhely–Gorzsa-Czukor-major is a well-known Neolithic site [21,45], associated with the Tisza culture in the Great Hungarian Plain, and is among the important tell settlements in the Carpathian Basin. The site lies at the confluence of the Tisza and Maros rivers, near the town of Hódmezővásárhely. Its extension is 7 ha; the full sequence is 2.6–3 m. It was systematically investigated over a larger area by Ferenc Horváth between 1978 and 1996. Detailed stratigraphic investigation has been carried out over a 1000 m^2 large area of the tell. The excavated layers contained remains of burnt houses, with two-storied buildings among them. Several burials were discovered from grave clusters in the uninhabited living spaces [21,45,46]. Long-term investigations on the polished stone tool assemblage of the site were published by Szakmány et al. [47,48] and Starnini et al. [49].

The Tápé-Lebő site (Alsó- and Felsőhalom), near the town of Szeged, has been the subject of intense archaeological interest since the very beginning of the 20th century.

Numerous small-scale excavations have been conducted in the area, which brought to light traces of settlements from the early Neolithic to the Middle Ages [50,51]. The tell rising above the floodplain lies at the confluence of the Tisza and Maros Rivers. A recent magnetometer survey has revealed that a 150 × 100 m oval, smaller mound partly bordered by oval ditches (Tápé-Lebő A) was enlarged to the east to create a larger, 300 × 150 m size, single large tell, also bordered by ditches (Tápé-Lebő B) [52]. Several scholars excavated the site, where 46 burials were uncovered and dated to the Tisza culture [50,53,54]. Altogether, eight burials contained stone tools, and all of them were located in Tápé-Lebő A (Alsóhalom) [54].

In this study, we investigated in detail 23 artefacts from Hódmezővásárhely-Gorzsa, Alsónyék-Bátaszék, and Lengyel-Sánc selected based on their macroscopic characteristics. These archaeological finds represent different tool types and are described in Table 1.

The investigation involved macroscopic characterization of all 234 samples and magnetic susceptibility (henceforth MS) measurement of 210 samples (except for artefacts from Zengővárkony), while instrumental analysis was performed on the 23-piece sample set. Bulk chemical composition determination was done by prompt gamma activation analysis (PGAA). Local chemical analysis and fabric investigation were performed by original surface scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (OS-SEM-EDS [55]).

Macroscopic characterization involved the morphometric measurements (height, length, and width; see dimensional data in the Supplementary Materials Table S1) and the determination of the general form (e.g., flat chisel or thick adze).

The MS measurements were done with a Kappameter KT-5 type handheld instrument. The final values were calculated with surface and thickness correction [47,56–58]. PGA analyses were done at the PGAA and NIPS stations of the Budapest Neutron Centre, HUN-REN Centre for Energy Research [59]. The samples were irradiated with a neutron beam of 1.2×10^8 cm^{-2} s^{-1} neutron flux and 24–44 mm^2 collimation. The excited gamma radiation was detected, and the spectrum was processed according to Révay [60]. Thus, the bulk major, minor, and some trace element composition of the sample was determined and quantified (e.g., [61–64]). The OS-SEM-EDS measurements were carried out on two instruments in two laboratories. An AMRAY-1830 type scanning electron microscope was applied at the Dept. of Petrology and Geochemistry, Eötvös Loránd University, Budapest [48,55]. The EDAX PV9800 type EDS detector has a built-in Be window, which limits the detection and quantification of $Z < 13$ elements. The measurements were done at 20 kV accelerating voltage and 1 nA beam current in a 10^{-6} mbar vacuum environment. A Thermo Scientific Scios2 Dual Beam scanning electron microscope was used at the Thin Film Physics Dept., HUN-REN Centre for Energy Research. The instrument has a Ga+ FIB coupled Schottky field-emission cathode. The measurements were done at 20 keV beam energy and 1.6 nA beam current in 10^{-5}–10^{-7} mbar vacuum environment. Chemical composition was measured with an Oxford X-max 20 SDD EDS detector. For these non-destructive original surface measurements, samples were wrapped into aluminum foil leaving only a small (few cm^2) window uncovered, therefore the sample was carbon-coated only in this window (see the preparation method on Figures 4 and 5 in [55] and on Figure 2 in [65]). The 50–100 nm thick carbon film could be completely removed from the artefacts after the investigations.

Table 1. Description of the instrumentally investigated 'whitestone' polished stone tools from the Late Neolithic of Southern Hungary.

No.	Archaeological Site	Inventory n. (Technical n.)	Tool Type	Colour	Size (L × W × H, mm)	MS (×10^{-3} SI)	Analysis
1	Lengyel-Sánc	HNM 52.46.8. (Lengyel-8)	thick adze	yellowish white	57 × 36 × 17	0.02	PGAA, OS-SEM-EDS
2	Hódmezővásárhely-Gorzsa	n.d. (GOR-352)	fr. of chisel cutting edge	white	45 × 17 × 14	0.01	PGAA, OS-SEM-EDS
3	Hódmezővásárhely-Gorzsa	n.d. (GOR-488)	chisel	yellowish white	80 × 25 × 22	0.03	PGAA, OS-SEM-EDS
4	Hódmezővásárhely-Gorzsa	n.d. (GOR-598)	reworked, polished axe/adze	white	61 × 47 × 15	0.02	PGAA
5	Hódmezővásárhely-Gorzsa	n.d. (GOR-404)	reworked polished axe/adze	pale yellowish white	70 × 42 × 20	0.01	PGAA, OS-SEM-EDS
6	Hódmezővásárhely-Gorzsa	n.d. (GOR-845)	cutting edge fr. of very flat chisel	white	52 × 32 × 8	0.01	PGAA
7	Hódmezővásárhely-Gorzsa	n.d. (GOR-293)	fr. of shoe-last (shaped) adze	white	56 × 26 × 28	0.01	OS-SEM-EDS
8	Hódmezővásárhely-Gorzsa	n.d. (GOR-900)	cutting edge fr. of chisel blade	greyish white, spotted	55 × 49 × 15	0.09	PGAA
9	Hódmezővásárhely-Gorzsa	n.d. (GOR-1044)	polished cutting edged tool	white	27 × 12 × 2	0.00	OS-SEM-EDS
10	Alsónyék-Bátaszék	M6-2010.10B.3060.1 (Any-23)	macehead	white	65 × 64 × 37	0.02	PGAA, OS-SEM-EDS
11	Alsónyék-Bátaszék	M6-2010.011.466.7 (Any-19)	macehead	white with dark grains	67 × 65 × 37	4.81	PGAA, OS-SEM-EDS
12	Alsónyék-Bátaszék	10B/3472/7899, Suppl.no.1 (Any-70)	flat chisel	yellowish white	48 × 36 × 12	0.02	PGAA
13	Alsónyék-Bátaszék	M6-2010.10B.2776.3 (Any-37)	flat chisel	yellowish white	34 × 32 × 11	0.00	PGAA
14	Alsónyék-Bátaszék	10B/3914/9249 (Any-73)	elongated thick adze	white	36 × 29 × 16	0.01	PGAA
15	Alsónyék-Bátaszék	M6-2010.10B.963.3 (Any-98)	shoe-last (shaped) adze	yellowish white	58 × 19 × 14	0.00	PGAA
16	Alsónyék-Bátaszék	10B/3913/9246, Suppl.no.1 (Any-72)	elongated flat adze	white	53 × 22 × 11	0.00	PGAA
17	Alsónyék-Bátaszék	M6-2010.011.2843.1 (Any-74)	flat chisel	yellowish white	41 × 22 × 7	0.00	PGAA
18	Alsónyék-Bátaszék	M6-2013.5603.1880.7 (Any-82)	flat chisel	light greyish white	33 × 25 × 7	0.08	PGAA
19	Alsónyék-Bátaszék	10B/3787/9255, Suppl.no.2 (Any-69)	flat chisel	yellowish white	27 × 24 × 7	0.00	PGAA
20	Alsónyék-Bátaszék	5603/1747/7267, Suppl.no.3 (Any-77)	flat chisel	yellowish white	25 × 19 × 6	0.00	PGAA
21	Alsónyék-Bátaszék	M6-2013.5603.1965.8 (Any-83)	macehead	(light greyish) white	60 × 42 × 31	0.01	PGAA
22	Alsónyék-Bátaszék	M6-2010.10B.6502.1 (Any-102)	very flat chisel	(light greyish) white	70 × 46 × 8	0.01	PGAA
23	Alsónyék-Bátaszék	5603/2001/40/2 (Any-71)	shoe-last (shaped) adze	white	57 × 32 × 31	0.01	PGAA

3. Results

The polished stone tools made from 'whitestone' represent smaller-sized artefacts (see height, length, and width data in the Supplementary Materials Table S1) compared to polished items of other lithology from the same lithic assemblages. This difference may correlate with the tool types of 'whitestone' items, i.e., the vast majority of 'whitestone' polished stone tools are adzes and chisels, and the common feature is the "flat form" due to the thin cross-section. The 'whitestone' artefacts are represented mainly by small-sized chisel tool types with highly similar morphometrical appearances. For instance, the macroscopically studied 'whitestone' adzes and chisels in the Alsónyék assemblages have an average length of 45 mm (min: 20 mm, max: 92 mm), a width of 32 mm (min: 12 mm, max: 70 mm), and a thickness of 14 mm (min: 4 mm, max: 51 mm) [66]. We applied the typological system that Dragana Antonović described and used for the polished stone material at Serbian Vinča sites [6]. We characterized the longer items as adzes, such as shoe-last (shaped) adzes, and the smaller, flat polished items as chisels (see Figure 2A), which are mostly the previously mentioned highly similar mass-produced items [6]. The third tool type is the maceheads, which are the only perforated 'whitestone' items in the investigated lithic assemblages (Figure 2B).

Macroscopic observation of 'whitestone' tools proves that this group of artefacts shows minimal variability and is relatively similar to each other, thus easily recognizable but not informative on the real lithology. It is a white-yellowish and white-greyish white, very fine-grained, homogeneous material. Its hardness, porosity, and compaction state can be very diverse from the lightweight, porous, easy-to-crumble condition to the heavier, compact, dense, and conchoidal fracturing, hard material. The magnetic susceptibility is dominantly very small or zero (0–0.03 $\times$ 10^{-3} SI). There were a few exceptions where higher MS values were detected due to the presence of dark mineral or rock fragments or brecciated veins (0.2–4.5 $\times$ 10^{-3} SI). Based on a comprehensive statistical study on polished stone tools of Alsónyék-Bátaszék [67], 'whitestone' tools are usually small-sized, lightweight (<100 g), and have varied density (2.3–3.1 g/cm^3). Based on these results, three main clusters could be identified: 'small sized-high density', 'small sized-low density', and 'large sized-medium density'.

Macroscopic description and MS value were the basic pieces of information found for the 210 polished stone tools (in the case of artefacts from Zengővárkony, no MS measurements were performed). These data, i.e., the general light-colored and fine-grained appearance and the near-zero MS value, provided the basis for the wider classification into the 'whitestone' category. In this category, based on petrographic determinations, there were general 'whitestone' (sometimes brecciated or argillaceous), fine-crystalline limestone or dolomite, diatomite, porcellanite, calcareous claystone and calcarenite, calcareous tuff, siliceous schist, or even lithified bone (see column 'Preliminary macroscopic petrographic category' in Supplementary Materials Table S1).

Based on the PGAA of 21 archaeological samples (Table 2), there are significant differences in the bulk chemical composition which is the primary basis of the categorization. Four main chemical types can be distinguished (Figure 3). The most common type (n = 10) contains 14–27 wt% MgO and 16–34 wt% CO_2 (which is the stoichiometrically equivalent amount for a $MgCO_3$ formula) and a significant quantity of SiO_2 (40–57 wt%). CaO content is 0.3–2.3 wt%, while H_2O content is 0.80–1.05 wt%. Other minor oxides (TiO_2, Al_2O_3, Fe_2O_3, and MnO) are near or below the detection limit of PGAA. Among the trace elements, boron shows significant enrichment with 100–300 μg/g concentration, while chlorine varies over a wide range (10–300 μg/g). Other detectable trace elements are below the detection limit of PGAA. One exceptional sample (Lengyel-8) shows similarities with this group (simultaneous MgO- and CO_2-enrichment, 9.91 and 9.51 wt%, respectively) but with much higher SiO_2 content (78.89 wt%).

Table 2. Bulk elemental composition of 'whitestone' polished stone tools measured by PGAA (major elements are in wt% and oxide form, trace elements are in µg/g and element form) (D.L. detection limit).

	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3^t$	MnO	MgO	CaO	Na_2O	K_2O	H_2O	SO_3	CO_2	P_2O_5	B	Cl	Sm	Gd
D.L.	0.90	0.03	0.10	0.02	0.01	1.5	0.30	0.70	0.09	0.03	0.40	3.0	1.0	0.5	20	0.3	0.2
Lengyel-8	78.89					9.9	0.64			1.05		9.5		0.5	70		
GOR-352	48.00			0.24	0.03	23.0	0.68	0.10		0.89		27.0		196	30		
GOR-404	44.34			0.06	0.02	26.9	0.72			0.99		27.0		102	21		
GOR-488	53.00	0.003		0.08	0.02	18.0	2.30	0.09		0.82		25.0		205			
GOR-598	68.00			0.03	0.01	14.0	0.42	0.05		0.92		16.0		347	14	4.4	5.0
GOR-845	40.40	0.000		0.03	0.01	25.8	0.64	0.09		0.94		32.0		241	14		
GOR-900	53.41	0.179	3.06	1.64	0.36	2.6	17.51	1.48	1.72	1.13		16.7		1980	126	3.0	2.3
Any-19	1.51	0.014	0.21	1.26	0.23	20.8	25.50			1.51		49.0		4.7	23	3.6	
Any-23	1.80			0.45	0.32	21.3	24.29			0.39		51.4			15	3.3	0.4
Any-37	42.21					22.4	0.30			1.01		34.0		150	34		
Any-69	47.83					20.0	0.62			1.04		30.4		126	39		
Any-70	62.77		0.15	0.12	0.02	18.0	1.03			1.03		16.8		228	78		
Any-71	25.72			0.18		14.0	24.30			2.14		33.6		24.5	17	0.4	0.2
Any-72	97.87			0.23			0.46			1.21				438	821		
Any-73	28.73	0.055	1.16	0.50	0.24		34.72	0.14	0.28	1.03		33.1		7.6	263	3.4	2.1
Any-74				0.29	0.02		34.88			10.31	0.53	28.5	25.4	4.5	849	0.4	0.3
Any-77	98.36			0.10						1.39				305	591		
Any-82	42.11	0.578	13.90	5.17	0.14	4.5	15.84	1.25	0.33	0.19		16.0		13.2	223	5.7	3.2
Any-83	2.21	0.031	0.64	0.28	0.02	25.9	21.49		0.09	0.96		48.4		5.2	13	0.5	0.2
Any-98	56.47		0.22	0.16	0.04	19.9	0.57			1.03		21.6		214	93		
Any-102	45.05	0.182	5.09	1.89	0.28	2.4	20.57	2.68	0.38	1.25		20.2		2.1	432	6.7	3.8

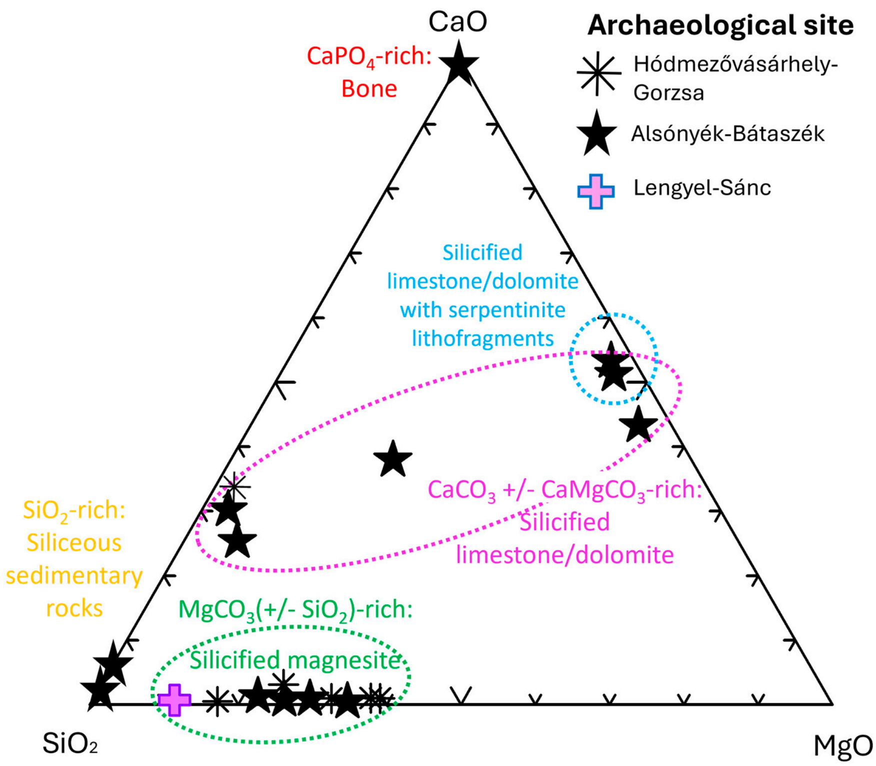

Figure 3. Major element composition-based classification of 'whitestone' polished stone tools (graphics: V. Szilágyi).

Another significant type (n = 8) is characterized by CaO-enrichment (34 wt%) or simultaneous enrichment in CaO (15–26 wt%) and MgO (2–26 wt%), both parallel with large CO_2 content (16–51 wt%, which is stoichiometrically equivalent to the amount for the $CaCO_3$ or $CaMg(CO_3)_2$ formula). In addition, relevant but varied SiO_2 concentrations can be detected (1–45 wt%). Amounts of other minor oxides, especially 'natural contaminants' like Al_2O_3 (0–14 wt%) or Fe_2O_3 (0.2–5.9 wt%), vary on a wide range from absent (below detection limit) to more than 10 wt%.

Two samples (Alsónyék-Bátaszék, Any-72, Any-77) predominantly consist of SiO_2 (>97 wt%) and are accompanied with large boron content (>300 µg/g). Another sample (Alsónyék-Bátaszék, Any-74) contains 34.88 wt% CaO, 28.45 wt% CO_2, 25.43 wt% P_2O_5, and 10.31 wt% H_2O together with a minimal amount of minor element oxides.

Based on the overall chemistry, the following chemical types were differentiated: (1) $MgCO_3$- and SiO_2-rich; (2) $CaCO_3$- or Ca-$MgCO_3$ (and SiO_2-)-rich; (3) $CaPO_4$-rich and (4) almost pure SiO_2 varieties (Figure 3, similarly on Figure 5 in [68]).

The most common type of 'whitestone' proved to be the $MgCO_3$- and SiO_2-rich type (Figure 4a,b). Based on detailed microscopic investigations, this is a micritic carbonatic and siliceous rock with crystalline quartz and chalcedony (Figure 4c). Mineral chemical investigations identified magnesite as the predominant carbonatic mineral phase (Figure 4d). Previously, X-ray diffraction analysis of a 'whitestone' chisel from Lengyel (WMM 1/933-221) belonging to this 'whitestone' type identified magnesite and quartz as the only mineral phases [34].

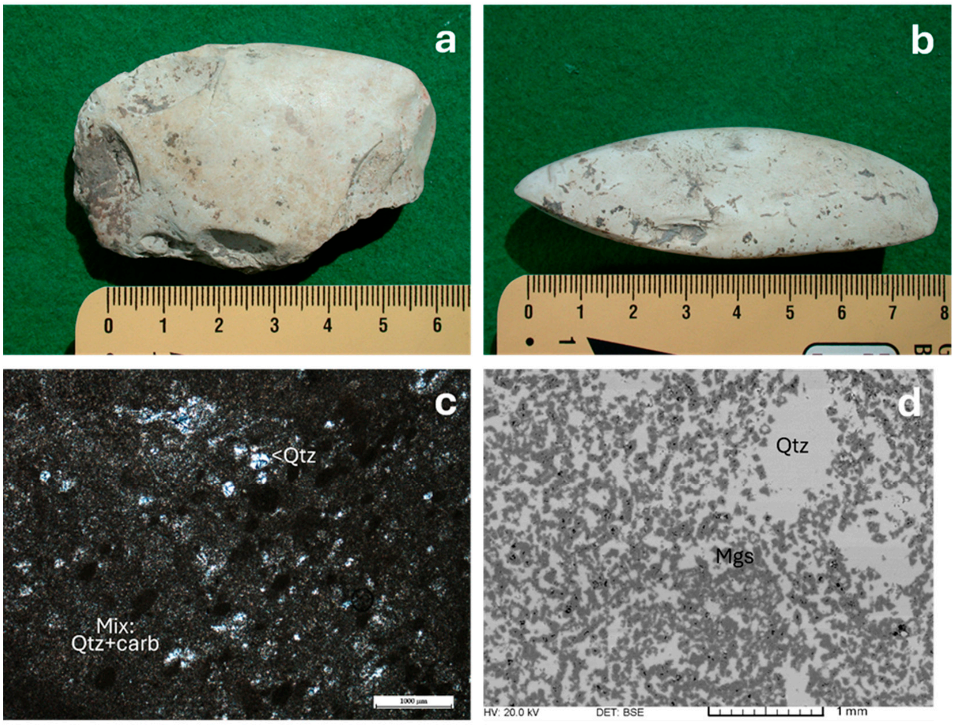

Figure 4. Macroscopic appearance, microscopic texture, and mineralogical composition of $MgCO_3$- and SiO_2-rich type of 'whitestone' polished stone tools. (**a**) Hódmezővásárhely-Gorzsa, GOR-404 (photo: Gy. Szakmány), (**b**) Hódmezővásárhely-Gorzsa, GOR-488 (photo: Gy. Szakmány), (**c**) optical microscopic image (GOR-404, XPL) (photo: Gy. Szakmány), (**d**) SEM-BSE image (GOR-404) with quartz (Qtz), magnesite (Mgs), and carbonates (carb) (photo: Z. Kovács).

Another abundant type of 'whitestone' is the $CaCO_3$- or Ca-$MgCO_3$ (and SiO_2-)-rich type. Due to the very fine-grained texture of this rock type, microscopic examinations did not provide detailed results on the mineralogical composition. It could be concluded that the matrix is composed of variable carbonates (calcite, dolomite, siderite?) and varied amounts of quartz (or chalcedony), and a lesser amount of opaque minerals [34]. In this group of artefacts two particular tools (Any-19 and Any-23) deriving from the Alsónyék-Bátaszék site gave the opportunity to research the origin of the rock type in detail. It was observed with the naked eye that the fine-grained white matrix of these two samples contains a few mm sized, crystalline, dark green-black lithofragments as remnants of the parent rock of this weathered lithology (Figures 5a and 6a). In addition, local MS measurements resulted in higher values (0.02–4.81 × 10^{-3} SI) than the average 'whitestone' matrix. The microscopic examinations showed that the white matrix of samples Any-19 and Any-23 consists of dolomite and calcite, which contain heterogeneous clusters of calcite–siderite–iron oxide (Figure 5b) and weathered lithofragments of serpentinite (including ortho- and clino-) pyroxene and spinel as relic inclusions and chlorite as vein-filling minerals in the serpentinized pseudomorphs, probably after olivine crystals; Figure 5c). Clusters of carbonates (calcite, siderite) and ironoxides form characteristic weathering crystal accumulations (Figure 5b). Larger pyroxene crystals (500–1000 µm) show compositional variability in the form of exsolution lamellae (Figure 5c,d) with monoclinic diopside and rhombic enstatite endmembers (Figure 5d). Serpentine minerals also form larger clusters and are segmented with veins of chlorite. Due to the presence of homogeneous and zoned spinel crystals (Figure 6b,c), there could be more spinel compositions detected. Homogeneous spinel crystals are predominantly chrome-spinels (or aluminum-chromites). Zoned crystals show chrome-spinel composition in the core while chrome-magnetite composition in the rim (Figure 6b,c).

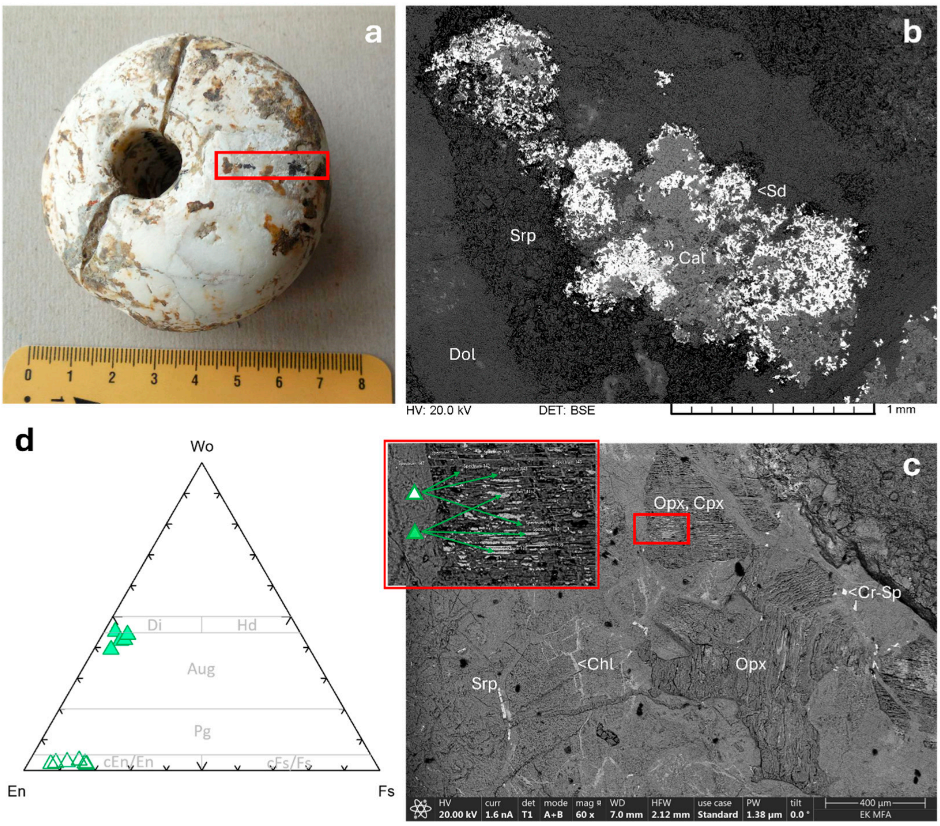

Figure 5. Macroscopic appearance, microscopic texture, and mineralogical composition of $CaCO_3$- or Ca-$MgCO_3$ (and SiO_2-)-rich type of 'whitestone' polished stone tools. (**a**) macehead (Alsónyék-Bátaszék, Any-19) made from a rock with white carbonatic matrix (dolomite) and dark green-black lithofragments (photo: Gy. Szakmány), (**b**) SEM-BSE image of the dark lithofragments (composing of serpentine minerals (Serp), siderite (Sd) and calcite (Cal)) and the white matrix (dolomite (Dol), Alsónyék-Bátaszék, Any-19), (**c**) SEM-BSE image of the dark lithofragments (composing of serpentine minerals (Srp), ortho- and clinopyroxenes (Opx, Cpx), chlorite (Chl) and chromium-rich spinel (Cr-Sp)) (Alsónyék-Bátaszék, Any-23) (**b**,**c** photos: Z. Kovács), (**d**) chemical composition of exsolution in pyroxene crystals (with monoclinic diopside (Di) and rhombic enstatite (En) compositions) (graphics: V. Szilágyi).

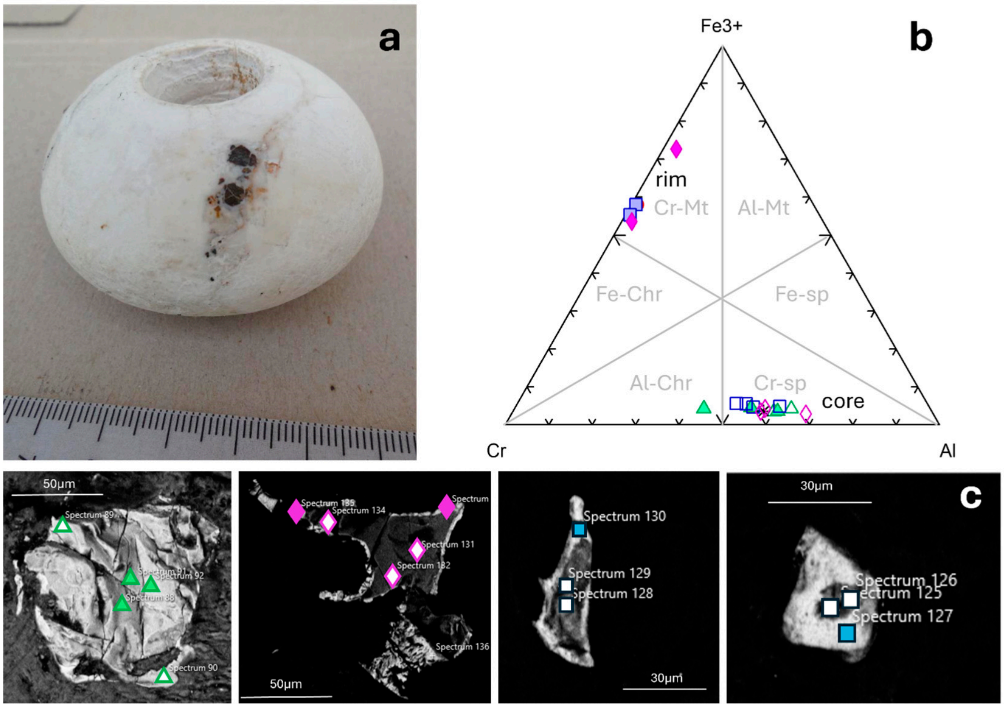

Figure 6. Macroscopic appearance and opaque mineral composition of $CaCO_3$- or Ca-$MgCO_3$ (and SiO_2-)-rich type of 'whitestone' polished stone tools. (**a**) macehead (Alsónyék-Bátaszék, Any-23) made from a rock with white carbonatic matrix (dolomite) and dark green-black lithofragments (photo: Gy. Szakmány), (**b**) chemical composition of spinels (core and rim of the crystals, Alsónyék-Bátaszék, Any-23) on the Fe^{3+}-Cr-Al triangular diagram [63]. Measured compositions fit the chrome-magnetite (Cr-Mt), aluminum-chromite (Al-Chr) and chrome-spinel (Cr-Sp) fields (graphics: V. Szilágyi). (**c**) SEM-BSE images of the spinel minerals with the measurement points (Alsónyék-Bátaszék, Any-23) (photo: Z. Kovács).

4. Discussion

We can conclude that 'whitestone' polished stone tools are adzes, chisels, and maceheads, and their primary archaeological contexts are burials and domestic pits attributed to the Late Neolithic period. Some elongated adzes are larger-sized items, but most of the 'whitestone' artefacts are represented in smaller-sized chisel tool types. These chisels have highly similar morphometrical appearances, which Dragana Antonović started to describe as Vinča 'whitestone' mass production [4,6]. All measured size parameters indicate that the forms of 'whitestone' artefacts exist within a very narrow range, regardless of the material quality.

In comparison, chisels are smaller than adzes, and besides the morphometric and typological differences, the function is also slightly different. The adzes were intended for greater exertion and to transmit greater force, achieved through swinging and striking, such as in wood chopping and general woodworking [69]. Due to the smaller sizes, chisels were not suitable for this function, and it is likely that the physical properties of the 'whitestone' material were not appropriate for this purpose. At the current stage of the ongoing research, use–wear analysis—which could help identify the function of the item—has not yet been conducted on the 'whitestone' items from Hungary (which contrasts the Serbian finds, where V. Dimić conducted it [69,70]). However, sharpened cutting edges and newly polished surfaces visible to the naked eye in the Alsónyék assemblage are the most common features. These characteristics suggest heavy usage of the 'whitestone' items both in the burial and domestic contexts (e.g., pits and ditches) [66].

There is no archaeological evidence on the production activity of 'whitestone' polished stone tools at Alsónyék or other previously excavated sites. This fact suggests that the 'whitestone' tools arrived as exchanged items to Late Neolithic settlements in present-day Hungary, where the inhabitants used them heavily (breaking, reshaping, retouching, etc.), which might have resulted in the decreasing dimensions of the tools.

The detailed study of the chemical-mineralogical composition of 'whitestone' polished stone tools resulted in four main compositional types. The most common $MgCO_3$- and SiO_2-rich type predominantly contains micritic magnesite and quartz–chalcedony, thus it can be interpreted as a silicified magnesite rock. The second most abundant type of 'whitestone' is the $CaCO_3$- or Ca-$MgCO_3$ (and SiO_2-)-rich type, which is composed of calcite–dolomite–siderite, quartz, and iron oxides. The lithology of this fine-grained type is limestone and/or dolomite with the variable extent of silicification (silicified limestone/dolomite). In addition, this type occasionally contains remnants of the parent (unaltered) rock, which—based on the calcite–siderite–iron oxide accumulations and weathered serpentinite lithofragments (serpentine minerals–pyroxene–chlorite–spinel)—was serpentinite. There are subordinate types of 'whitestone' with $CaPO_4$-rich and SiO_2-rich compositions; these are fresh or lithified bone (apatite) and siliceous rock varieties.

Considering the predominance of silicified magnesite and serpentinite-derived carbonatic lithologies, it is important to know that such rocks are typical in the alteration zones of serpentinized ultramafic rocks. Decomposition of serpentine minerals and relict phases (mainly olivine) produces reactive Mg^{2+} and H_4SiO_4 compounds, which might react with accessible CO_2 and Ca^{2+} ions [71–73], resulting in the formation of dolomite, calcite, and magnesite. Due to the mobilization of SiO_2, a large amount of micro-cryptocrystalline silica may also precipitate or migrate away, which increases the porosity of the altered rock.

Serpentinized ultramafic rocks of the Carpathian Basin and its closer surroundings (connected to the Alpine, Carpathian, and Vardar–Dinarid orogenic zones) are potential sources of 'whitestone' (Figure 7). Alpine serpentinites are found in Burgenland, Styria, and Hohe Tauern in present-day Austria and Pohorje in Slovenia [74,75]. Carpathian serpentinites have outcrops in Southern Slovakia [76]. In addition, there are extended serpentinite bodies in the Sudetes of the Bohemian Massive (e.g., Gföhl Massive) [77]. It is only the Sudetes where evolved magnesitic alteration can be observed [77]. Considering that the observed archaeological material derived from the Southern Hungarian region and has analogies in Serbia and Bosnia and Herzegovina, the southern source, i.e., the Vardar–Dinarid Ophiolitic Belt, might logically draw our attention. Most of the known Serbian serpentinite outcrops (Fruška Gora, Srednja Bosna, Šumadija, Zlatibor, Kopaonik) [6,78–80] have extended magnesitic alteration zones. The connection between the Vinča culture 'whitestone' polished stone tools and the magnesitic weathering zones of Serbian serpentinites was determined based on field survey, macroscopic comparisons with 'whitestone' artefacts and experimental studies [6,70]. Our research identified a direct connection between the dolomites and serpentinites, which couples this 'whitestone' type with the magnesite sources. Further study on these raw materials will be necessary to conclude our provenance research on 'whitestone' polished stone tools in the cases of silicified magnesite and serpentinite-derived carbonatic lithologies, and even for some siliceous rock varieties.

Other, less relevant 'whitestone' lithologies, like bone (which is clearly not a real 'stone' tool raw material) and siliceous sedimentary rock, have locality-independent sources that cannot be traced further.

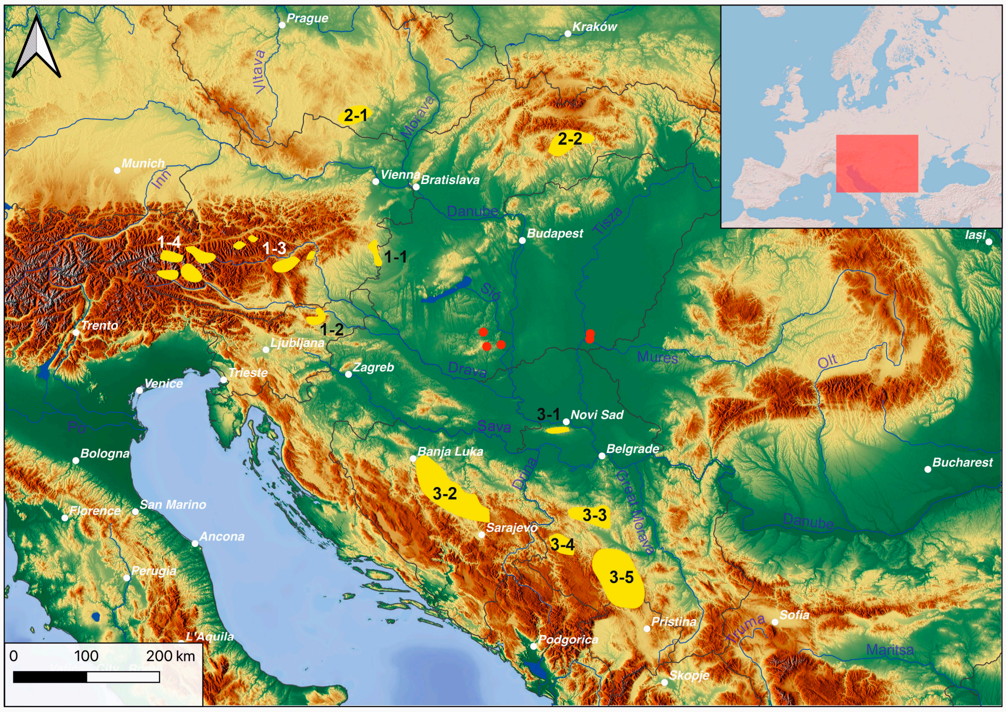

Figure 7. The location of archaeological sites (red dots) of the examined 'whitestone' polished stone tools with the serpentinized ultramafic rocks around the Carpathian Basin (yellow shapes with numbers). Alpine serpentinites: (1-1) Burgenland, (1-2) Pohorje, (1-3) Styria, (1-4) Hohe Tauern. (2-1) Serpentinites of the Sudetes, and (2-2) of the Carpathians, Southern Slovakia. Vardar–Dinarid serpentinites: (3-1) Fruška Gora, (3-2) Srednja Bosna, (3-3) Šumadija, (3-4) Zlatibor, (3-5) Kopaonik. The maps are provided by https://maps-for-free.com/layer/relief/z%7Bz%7D/row%7By%7D/%7Bz%7D_%7Bx%7D-%7By%7D.jpg, accessed on 6 March 2025. The projection is in EPSG:23700; HD72/EOV for the maps. Map made by Kata Furholt.

Our research is limited to a small sample set of the extended 'whitestone' assemblage of the studied Tisza and Lengyel culture sites (Hódmezővásárhely-Gorzsa, Alsónyék-Bátaszék, Lengyel-Sánc). However, macroscopic petrographic observations covered 234 artefacts, while magnetic susceptibility measurements were obtained on 210 artefacts (see Supplementary Materials Table S1). By linking our macroscopic determinations back to the results of the instrumental investigations, we can establish that most of the artefacts generally described as pure white, dense 'whitestone' with a smooth surface—and it was the predominant part (84%) of the assemblages—belong to the silicified magnesite type. There are some less certain and rarely determined macroscopic categories, like diatomite and porcellanite, which can also be interpreted as belonging to the silicified magnesite type [35]. However, a smaller part (14%) of the macroscopically determined general 'whitestone' category has a description mentioning brecciated texture or dark-colored veins and fragments, or argillaceous nature. These samples most probably belong to the serpentinite-deriving $CaCO_3$-$CaMgCO_3$ type. In addition, this is the category of macroscopically determined limestone, dolomite, and calcareous claystone samples. Comparing with the three clusters differentiated by Sági et al. [67] at Alsónyék-Bátaszék, the 'small sized-large density' cluster is equivalent to the variably silicified magnesite type, the 'small sized-small density' cluster can be fit with the dolomite/limestone type without remnants of serpentinite, and the 'large sized-medium density' cluster covers that part of the dolomite/limestone type, which contains serpentinite lithoclasts. A very subordinate part (2%) of the artefacts was identified as siliceous–calcareous rock with sedimentary features (e.g., probable diatom content, chert, or bone-like texture), which are considered siliceous sedimentary rocks in general or bone.

Macroscopic observations—confirmed or partly modified by instrumental investigations—resulted in the following diversification in lithotypes of the 'whitestone' technical group (see the last two columns, 'Preliminary macroscopic petrographic category' and 'Probable (partly revised) petrographic category based on this research' in Supplementary Materials Table S1). The predominant type (84%) is the silicified magnesite at all archaeological sites which generally was used to manufacture flat or shoe-last (shaped) adzes with poorly preserved to highly polished surfaces. The serpentinite-deriving dolomite/limestone type covers a subordinate part (14%) of the assemblages, and all the maceheads belong to this group together with flat adzes. A very limited quantity (2%) of real siliceous sedimentary rocks can be supposed under this 'whitestone' technical name. The sole bone sample from Alsónyék-Bátaszék is considered to be an imitation of a polished stone adze.

5. Conclusions

'Whitestone' is a characteristic polished stone tool raw material in the Late Neolithic of the Southern Carpathian Basin (Vinča, Lengyel, and Tisza cultures) to produce specific tool types with fairly standardized dimensions. Due to its peculiar appearance, it was recognized from the early stage of archaeological research [28] but with inhomogeneous interpretation of the material and without understanding its origin.

Due to the archaeometric investigations presented in this paper, the complexity of the lithology can be understood in detail. The predominant silicified magnesite type and subordinate serpentinite-deriving dolomite/limestone type are proposed to have a common origin in the alteration zone of extended serpentinite bodies, which is evidenced with mineralogical-chemical data, most probably in Serbia (Fruška Gora, Srednja Bosna, Šumadija, Zlatibor, and Kopaonik). The Serbian raw material source was theoretically accepted as the provenance of Vinča culture 'whitestone' polished stone tools [6]. The exclusive presence of final products, smaller sizes, and traces of extensive use suggests that the 'whitestone' tools arrived as exchanged items to Late Neolithic settlements of present-day Hungary. This is in agreement with the clear distribution pattern of 'whitestone' in Serbia [81], where, by the distance from the primary sources, different steps of *chaîne opératoire* (from primary reduction to final product) could be identified. Our conclusion supports the idea of a social and economic network connection of the Lengyel and Tisza communities with the Vinča culture during the Late Neolithic.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/heritage8030112/s1: Table S1. Macroscopically identified 'whitestone' artefacts in the Late Neolithic of Southern Hungary (n = 234).

Author Contributions: Conceptualization, V.S. and G.S.; methodology, G.S.; software, K.F., Z.K., and V.S.; validation, V.S. and G.S.; formal analysis, V.S.; investigation, I.H., Z.K., and V.S.; resources, A.O. and K.F.; data curation, G.S. and V.S.; writing—original draft preparation, V.S., K.F., A.O., Z.K., and G.S.; writing—review and editing, V.S.; visualization, V.S. and K.F.; supervision, G.S.; project administration, G.S.; funding acquisition, G.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

PGAA	Prompt Gamma Activation Analysis
SEM-EDS	Scanning Electron Microscopy Coupled with Energy Dispersive Spectrometer
BCE	Before Common Era
MS	Magnetic Susceptibility
OS-SEM-EDS	Original Surface Scanning Electron Microscopy Coupled with Energy Dispersive Spectrometer
HUN-REN	Hungarian Research Network
HNM	Hungarian National Museum
WMM	Wosinsky Mór Museum
BSE	Backscattered Electron

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