

THE MICROMINERALOGICAL COLLECTION OF THE MINING AND GEOLOGICAL SURVEY OF HUNGARY

A MAGYAR BÁNYÁSZATI ÉS FÖLDTANI SZOLGÁLAT (MBFSZ) MIKROMINERALÓGIAI GYŰJTEMÉNYE*

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Abstract

The Mining and Geological Survey of Hungary (MBFSZ) owns a comprehensive collection of mineral resources in Hungary. This paper presents the micromineralogical collection of MBFSZ belonging to the Mineralogy and Economic Geology Collection which provides information on the heavy mineral (HM) assemblages of clastic sediments (sand, gravel) of Hungary. The collection covers the whole territory of the country with 754 localities including open-air quarries exploiting Miocene-Holocene sand or gravel, recent river bars, shallow drillings exploring Pleistocene sediments of alluvial cones. The collection comprises altogether 863 sampling points and 4326 individually inventoried heavy mineral separata.

We summarize the stormy history of the collection, the sampling and processing strategy, the data available and the accessibility of the micromineralogical collection. Our aim is to draw attention to the collection, to describe it and acquaint researchers who are interested in carrying out research on these clastic sediments in any field of science. There is a special emphasis on the potential archaeometric applicability of the micromineralogical collection.

Kivonat

A Magyar Bányászati és Földtani Szolgálat (MBFSZ) jelentős, a magyarországi ásványi (nyers)anyagokat felölelő gyűjteménnyel rendelkezik. A jelen cikkben bemutatott mikromineralógiai gyűjtemény – amely a Szolgálat Ásványtan–Teleptani gyűjteményének részét képezi – a hazai törmelékes üledékek (homok, kavics) nehézasvány összetételéről ad információt. A mintavétel egész Magyarország területét lefedi. A gyűjtemény 754 lelőhely (miocén-holocén korú homokot és kavicsot termelő bányák, recens folyózatonyok, folyóvízi hordalékkúpok pleisztocén üledékeit feltáró sekélyfúrások) 863 mintavételi pontjáról származó felszíni és felszínközeli laza üledék 4326 db egyedileg leltározott nehézasvány-szeparátumát tartalmazza.

Munkánkban a gyűjtemény viszontagságos történetét, a mintavétel és a feldolgozás módszertanát, a rendelkezésre álló adatokat, illetve a jelenlegi hozzáférhetőséget ismertetjük. Célunk, hogy a kutatók – legyen szó bármilyen, a törmelékes üledékes kőzetek felhasználásával foglalkozó szakemberről – megismerjék és saját kutatásaikhoz hasznosítsák ezt a rendkívül átfogó gyűjteményi anyagot. Cikkünkben külön felhívjuk a figyelmet a mikromineralógiai gyűjtemény – talán nem azonnal szembeötlő – archeometriai felhasználási lehetőségeire.

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KULCSSZAVAK: MIKROMINERALÓGIA, NEHÉZÁSVÁNYOK, ÖSSZEHASONLÍTÓ GYŰJTEMÉNY, KERÁMIA-PROVENIENCIA, MAGYARORSZÁG



Fig. 1.: Original map of the sampling localities (1:500,000, on tracing paper)

1. ábra: A mintavételi helyek eredeti térképe (1:500 000, pauszon)

Between the acceptance and the publication of this article, the Supervisory Authority of Regulatory Affairs (SARA) became the successor of the Survey.

Historical overview

Establishment of the micromineralogical collection – Results and deficiencies of the project ‘The study of the recent and fossil river bars of Hungary’

The project ‘The study of the recent and fossil river bars of Hungary’ (1986-1992) ran by the Mining and Geological Survey of Hungary (MBFSZ) aimed – in addition to the discovery of economically exploitable gold, rare earth elements and other raw materials – to understand the sedimentation history of the filling-up Pannonian Basin. As a fundamental element of this large-scale research plan a micromineralogical collection representative for Hungary and a handbook of the methodology of mineral determination were established. The project was stopped abruptly in 1992 due to not living up to economic expectations, and the research remained unfinished.

According to the original plan, based on the recommendations of Andrew E. Grosz (United

States Geological Survey), the 15-years-lasting project could gain samples and heavy mineral (HM) separata from four main sources:

- recent or sub-recent sediments of major rivers (point bars) in Hungary,
- Tertiary to Pleistocene sediments exploited for construction purposes (sand and gravel quarries),
- older alluvial cones of recent rivers sampled by shallow drillings (started with rivers Danube and Maros)
- core samples from conventional drillings available in the core inventory of the MBFSZ (Kuti & Síkhegyi, 1985)

Sampling of recent point bars and quarries was successfully finished in 1986-1990. Shallow drillings of alluvial cones were in an advanced stage when stopped abruptly in 1991. Drillings were fulfilled in Győrzámoly, Gönyű, Mecsér, Csepel island (Ráckeve) and Deszk. Selection of materials from conventional drilling cores at the core inventories was not realized.

Some localities provided more samples, e.g. different layers of sand quarries, different positions

of point bars. However, with some exception, one sample per locality was usually processed during the sample preparation. In most cases, the selected samples adequately represent each locality.

Preparation for investigations and analyses were mostly fulfilled. The investigations involved general sedimentology, mineralogy of grains, trace element spectroscopy of <0.063 mm fraction, and combined heavy mineral study (see later its explanation) of almost half of the samples.

Immediate abruption of the project (in a few weeks) resulted in the lack or incompleteness of collecting, evaluating and publishing data. In addition, as an unfortunate turn, unpublished research reports (on sedimentology and spectroscopy), field records and sketches of the sampling localities generated at different research groups were mostly lost.

In lack of the documentation, samples of the micromineralogical collection – though remained together – became unevaluatable. Additional problem was the vulnerable mode of the sample storage, just a small part of the samples (deriving from shallow drillings) was stored in lockup glass vials, while the majority was collected into thin paper bags. The sole item documenting the sampling was a single copy of the 1:500 000 scale map with the sampling locations (**Fig. 1**).

2016, the year of the change

In 2016, due to a lucky coincidence, most of the sketches of sampling localities and the field reports on the surface sampling were found. It made possible to decode both the locality (e.g. river sections or open-air quarries) numbers and the subsite sampling points (e.g. 'middle of the point bar', 'northern wall of the quarry, third layer'). In addition, information on the dominant grain size range ('gravelly sand', 'sandy silt') was also recovered.

Based on this information – and due to the significant financial and manpower expenditure of the MBFSZ – digitalization of the data (field reports, hand-write manuscripts), georeferenced digitalization of the sampling map and the exact identification of the sampling localities by the sketches and field reports was started. In addition, rescue of the bad-preserved heavy mineral samples was fulfilled to prevent further deterioration and to provide fast retrieving and professional storage and register (Gyuricza et al. 2017, Péterdi et al. 2020).

The micromineralogical collection: from the sample selection to the data base

Sampling strategy

The sampling procedure covered the whole territory of Hungary: sand and gravel quarries, recent point bars, and shallow drillings of Pleistocene sediments

from alluvial cones. In many cases more samples from a location were selected. For instance, at recent river bars – where HMs are concentrated to the upper, depositional side, while the middle and the eroding lower parts are less enriched – 4 to 6 subsamples were collected depending on the size of the point bar. Similarly, if more layers could be differentiated more subsamples were selected at open-air quarries. Another situation was when transport-ready grain size fractions were gathered from the depo of a single quarry. Such sampling was documented in each case.

There are data about 983 samples (see in the **Appendix 1**). However, the number of samples which can be actually investigated is much less since the sample processing usually was limited to one sample by site, except for some instances.

Amount of the samples is proportional to the average grain size of the sedimentary formation; i.e. 100 kg from coarse- and medium-grained gravel, 50 kg from fine-grained gravel, 25 kg from very fine-grained gravel, and 10 kg from coarse- to medium-grained sands. Sampling of fine-grained sand or finer-rich sediments was not the scope of the project since those are not potential formations for accumulation of heavy minerals (Molnár 1987). In addition, representative samples of the bulk were separated for basic laboratory investigations (granulometry, conventional HM study); i.e. 2–3 kg from gravels, 0.5–1 kg from sands (Molnár 1987).

Sample preparation

In order to minimize the transported sample amounts, gravel fraction of the sediments was on-site separated by wet screening using 48-, 20- and 5-mm screen gauges. From the weighed fractions, finers were transported to the laboratory while a smaller representative portion of the gravel fraction was also collected for petrographic investigation and shape analysis (Molnár 1987).

Differentiation in the 0.5–2 mm range was done in the laboratory by wet screening using 2-, 1- and 0.5-mm screen gauges. Coarse- to fine-grained sands and the finer fractions were separated by wet sieving using 0.25-, 0.125- and 0.063-mm sieve gauges. In all stages of the separation dry weighing was the final step (Molnár 1987).

In the early stage of the project, HM concentration was done from the 0.063–0.5 mm fraction by bromoform in spiral and beaker. Later on and on the majority of the samples, the huge amount of sediment fractions (150–200 g on average, but in some cases more than 1 kg) required another technique. HM concentration was fulfilled using a large, 15 cm diameter funnel and collecting flasks equipped with vacuum pump to prevent the evaporation of the bromoform. Wash-out of



Fig. 2.:
Micromineralogical collection
of the MBFSZ

2. ábra:
Az MBFSZ mikromineralógiai
gyűjteménye

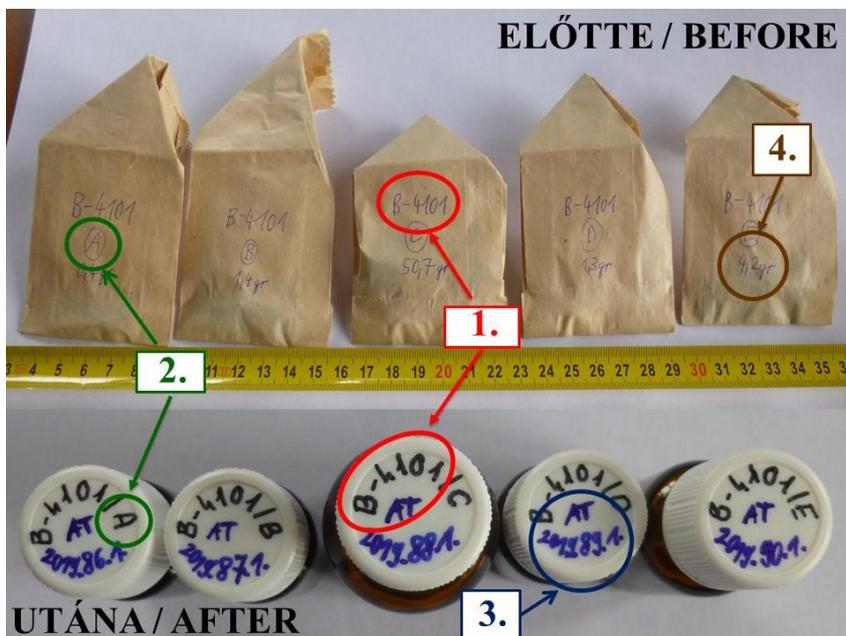


Fig. 3.:
State of the separata before and
after the repacking – legend:

1. sample ID, 2. fraction sign,
3. inventory number, 4.
- original mass of the fraction

3. ábra:
Szeparátumok átcsomagolás
előtt és után–azonosítók:

1. minta jele, 2. frakció jele, 3.
- leltári szám, 4. a frakció
eredetileg bemért tömege



Fig. 4.:
Five fractions of a single
sample after the repacking

4. ábra:
Egy minta 5 frakciója
átcsomagolás után

Fig. 5.: Record of an individually registered fraction (1 pc. of glass vial) in the database:

1. inventory number, 2. mark of the locality (sampling site) on the map, 3. sample code, 4. fraction code, 5. grain size of the original sample, 6. original weight of the fraction, 7. locality (settlement), 8. detailed description of the sampling locality, 9. repository, 10. name of the collecting person, 11. date of sampling

5. ábra: Egyedileg leltározott frakció (1 üvegcsé) rekordja az adatbázisban:

1. leltári szám, 2. leíróhely (mintavételi hely) térképi jele, 3. minta jele, 4. frakció jele, 5. eredeti minta szemcsemérete, 6. a frakció eredetileg bemért tömege, 7. leíróhely (település), 8. mintavételi hely részletes leírása, 9. elhelyezés, 10. gyűjtő neve, 11. gyűjtés ideje

bromoform from the mineral grains happened with ethyl alcohol or acetone (Gyuricza 1987).

HM separata were further divided into subsamples for conventional polarizing microscopic examinations, geochemical investigations and repository purposes. Unfortunately, these subsamples were ultimately lost. The remaining portion, at least half (usually 75%) of the whole HM separata was further processed by electromagnetic separator at different current values (0.0 A or hand magnet, 0.3 A, 0.6 A, 1.0 A and maximum at 2.4 A) (Parfenoff et al. 1970; Gyuricza 1986, 1987). These preparatory works were done earlier at the University of Miskolc (ME), then at the Hungarian Central Institute for the Development of Mining (KBFI).

As a result, the 0.063–0.5 mm fraction of the sediment samples was separated into 5 or 6 HM fractions indicated with letters from 'A' to 'F' and concentrating different minerals. It should be noted that the determination of mineral species is partly uncertain and inaccurate (see in detail in the next chapter). Fraction 'A' is the ferromagnetic one enriched in magnetite. Fractions 'B' to 'D' are the paramagnetic ones concentrating ilmenite and

hypersthene in 'B'; garnet, other pyroxenes and magmatic amphibole in 'C'; metamorphic amphibole, epidote-zoisite, and staurolite in 'D'. Imperfect separation of phases was due to the variable iron content of the mineral species. Fraction 'E' and 'F' are the diamagnetic part (containing e.g. zircon, kyanite and native gold) which was separated from the residual light minerals (e.g. quartz, feldspars) by bromoform. Differentiation by letters refers to the laboratory performing the sample preparation, i.e. 'E' for the KBFI and 'F' for the ME.

Rescue of the collection: repacking and register

It took two years (2017-2019) to repack the HM separata from the vulnerable thin paper bags and glass vials into safe lockup glass vials and jars having screw-caps paying a special attention to prevent the sample loss. Original sample codes and new standardized inventory numbers were marked both in the vials on paper cards and on the caps (**Figures 2–4**).

The inventory book is presented both in printed and electronic format; the later one is a digital searchable database. The inventory contains the

locality information like the name of the settlement and the exact description of the site (e.g. location of the quarry, position of the outcrop in the quarry, position of the sediment layer sampled, and depth interval of the shallow drilling). In addition, it also records the original locality and sample codes, the general description of the sediments (e.g. fine gravelly sand, fine sandy silt) and the originally weighed mass of the fractions of the HM separata by each sample (Fig. 5). Unfortunately, after fulfilling the investigations (see in details in section 'Micromineralogical studies, HM spectra') the observed separata were discarded due to lack of storage space. However, subsamples for repository purposes (i.e. for documentation) remained untouched and thus by their amounts clearly represent the original bulk samples. In addition, the amount of these subsamples reaches or exceeds that of ones necessary for HM study in general.

Actual state of the collection, accessibility and opportunities of new investigations

In its actual state, the micromineralogical collection belonging to the Mineralogy and Economic Geology Collection of the MBFSZ consists of 4326 individually inventoried heavy mineral separata (i.e. grain amounts stored in safe lockup glass vials) (Fig. 3). The collection covers the whole territory of the country with 863 sampling points of surface and near-surface sediments (Fig. 6). The sampling points derive from 754 localities: 510 open-air quarries exploiting Miocene-Holocene sand and/or gravel, Pleistocene sediments of 145 recent river bars and 99 shallow drillings exploring alluvial cones. The digital map and database (see in the Appendix 1) provides information on each sample and subsample (separatum). The searchable database can be connected via the following url: <https://gvujtemeny.mfgy.hu> (28.11.2021.).

The samples are deposited at the collection of the MBFSZ and are accessible according to the actual regulations of the Survey (e.g. the collection was not opened to external visitors or researchers during the COVID-19 pandemic). The research in the collection is supported by binocular and polarizing microscopes. It is a requirement of the MBFSZ to provide a copy of the documentation and publications on the results gained from the samples of the micromineralogical collection.

Samples which were not investigated during the original research project can be studied exclusively in a complete way, i.e. all fractions has to be observed and documented (min. a list of minerals present). Samples undergone earlier (during the

1990ies or since 2016) investigations can be studied even by fractions.

Micromineralogical studies, HM spectra

The project 'The study of the recent and fossil river bars of Hungary' was incomplete due to the sudden interruption, thus, until now approx. the half of the HM separata, 426 samples were investigated by the following protocol. The methodology was designed to the special requirements of the project and a combination of techniques was applied. The first step was the separation of the <0.1 mm grain size portion of fractions 'B', 'C', 'D', 'E' and 'F' for spectrographic analyses. Heavy mineral study was fulfilled on the complete 'A' (ferromagnetic) fraction and the >0.1 mm part of 'B' to 'F' (para- and diamagnetic) fractions (Molnár et al. 1990).

Due to the large sample number and amount, a geography-based selection was applied during the evaluation. It implied that samples from each region were divided into two subgroups: Group 1 (approx. one third of the samples by regions) observed in details and Group 2 (approx. two thirds of the samples by regions) undergone a basic examination. The detailed study involves both stereo- and polarizing microscopic investigations. Under the stereomicroscope, sample fractions were divided into mineral groups based on their color and shape. Further investigations of these mineral groups were done under the polarizing microscope to determine their heterogeneity. From the heterogeneous 'oligomineralic' groups (containing a few phases) mineral separata were prepared and the mineral species were identified. Such 'oligomineralic' groups were e.g. the 'green paramagnetic minerals' which proved to be a mixture of green amphiboles, augite, epidote, sometimes chlorite, and weathered mafic silicates (dominantly pyroxene and amphibole, so-called 'pyriboles'). In addition, in 1-2 samples by regions ('Group 1 selected samples'), all mineral species differentiated by stereomicroscope were studied as mineral preparata under the polarizing microscope for the exact determination.

The basic examination on Group 2 samples contained the sole general stereomicroscopic investigation and the division into the mineral groups known from the detailed studies on Group 1 samples. Mineral quantities undetermined by this method were estimated using the known (from the detailed studies on Group 1 samples) mineral ratios of samples from the same region (Molnár et al. 1989, 1990).

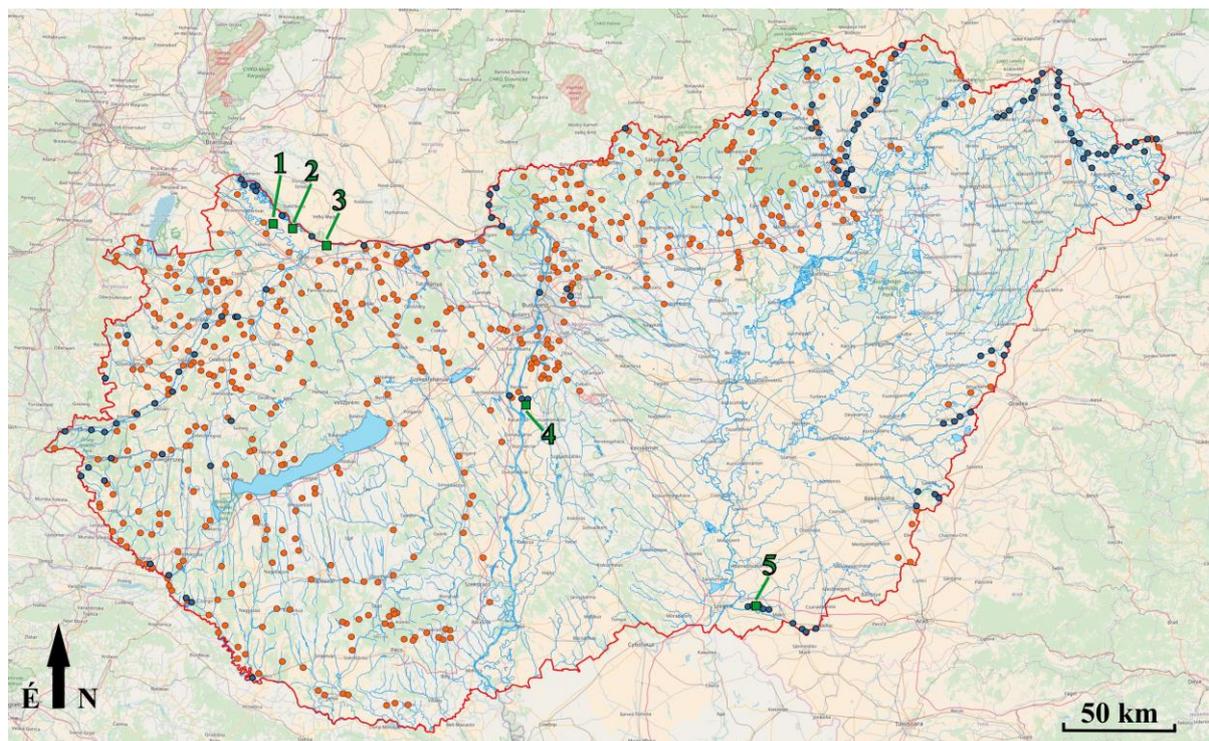


Fig. 6.: Digitalized map of the sampling localities: orange circles – sand and gravel quarries, blue circles – recent riverbars, green circles – shallow drilled sites (Pleistocene sediments of alluvial cones): 1. Mecsér, 2. Győrzámoly, 3. Gönyű, 4. Ráckeve (Csepel island), 5. Deszk

6. ábra: Digitalizált lelőhelytérkép: narancssárga körök – homok- és kavicsbányák, kék körök – recens folyózatonyok, zöld négyzetek – sekély fúrásokkal feltárt területek (folyóvízi hordalékkúpok pleisztocén üledékei): 1. Mecsér, 2. Győrzámoly, 3. Gönyű, 4. Ráckeve (Csepel-sziget), 5. Deszk

The selective methodology resulted in a much faster evaluation of the enormous sample amount. The detailed method on ‘Group 1 selected samples’ required 3-5 day/sample, while on other Group 1 samples took only 1 day. Receiving knowledge on the smaller part of the samples (Group 1) further studies on the larger part (Group 2 samples) could be done by 3-5 sample/day speed (Molnár et al. 1989). Time-demand of quantitative evaluation on each mineral separatum depended on the complexity (mono- or oligomineralic).

Based on the experiences (Molnár et al. 1989), the first, homogeneous mineral category, reliably differentiated by stereomicroscopy, contains the magnetite and ooidal magnetite, titanomagnetite, hematite, gold, garnet (*pyrope*, *almandine*), hypersthene type 1 (ferrohypersthene/ferrosilite), *anthophyllite*, sillimanite, staurolite, muscovite, chlorite, biotite, dolomite having aggregate form, limonite, ‘leucoxene’ (a mixed alteration product of Fe-Ti oxides (ilmenite, anatase, rutile, titanomagnetite) including titanite, perovskite), marcasite, and pyrite. In addition, ilmenite, rutile and tourmaline can be also clearly determined in samples which are easily separable by magnetic

methods. Phases of this homogeneous mineral category could be exactly quantified both by the detailed (Group 1) and the general (Group 2) methods. The only exceptions were the species indicated with *italics* which proved to be misdetermined during the later electron microprobe analyses (see explanation in the followings).

The second stereomicroscopic category of minerals consists of phases which are present both as relatively homogeneous monomineralic fractions and as members of oligomineralic groups. Such mineral species are hypersthene type 2 (ordinary hypersthene), green epidote, rutile type 1 (red), rutile type 2 (black), zircon, kyanite, tourmaline, and glauconite. In addition, altered or encrusted grains, and lithofragments belong to this category. Quantitative determination of minerals belonging to this category is strongly dependent on the results of detailed investigations on samples of the same region (Molnár et al. 1989).

The third stereomicroscopic category of minerals includes phases present in heterogeneous oligomineralic fractions, e.g. chromite, diopside, augite, tremolite, actinolite, green amphibole (hornblende), brown amphibole, oxyamphibole,

glaucophane, alkaline amphiboles in general (e.g. riebeckite), weathered mafic silicates (dominantly pyroxene and amphibole, so-called 'pyriboles'), colorless epidote, *yellow epidote*, clinozoisite, zoisite, corundum, anatase, andalusite, topaz, titanite, vesuvian, chloritoid, monazite, apatite, baryte, siderite (usually a mixture of siderite and carbonates), dolomite, quartz (or quartzose lithofragments), volcanic glass, and feldspar. (The species indicated with *italics* were falsely determined based the later electron microprobe analyses, see explanation in the followings.) In addition, altered or encrusted grains, and lithofragments also belong to this category. In specific cases minerals belonging to this third category can be easily separated as monomineralic fractions (e.g. in the absence of augite, green epidote can be clearly differentiated from other paramagnetic green minerals). Quantitative determination of minerals belonging to this category is not possible by stereomicroscopic method (Molnár et al. 1989). In these cases, estimation of mineral ratios is possible by the extrapolation of data from detailed investigations.

According to the experiments to quantify the error of the applied methodology, the standard error of the quantitative estimations is below 10% (Molnár et al. 1989).

In order to check the mineral identifications, electronmicroprobe (EPMA) investigations were carried out at the Geochemical Laboratory of the Hungarian Academy of Sciences on monomineralic separata of phases and phase groups listed in **Table 1** (Polgári 1988, 1989, 1990, 1991, Molnár et al. 1989). Some mineral species were investigated in more preparata per regions. As a result of these control investigations (Polgári 1988, 1989, 1990, 1991, Molnár et al. 1989), separata proved to be monomineralic in case of the following minerals: apatite (2 cases out of 3), augite, brown amphibole, biotite, altered amphibole, zircon, diopside, diopside augite, kyanite, dolomite (2 cases out of 3), epidote type 1 (green epidote), ferrohypersthene (ferrosilite), glauconite, hematite (2 cases out of 6), hypersthene (both types 1 and 2), ilmenite (1 case out of 2), chlorite, leucoxene (1 case out of 2), oolitic magnetite, muscovite, oxyamphibole (basaltic amphibole), pyrite, rutile (1 case out of 2), sillimanite, staurolite, titanite, tourmaline, zoisite and green amphibole (Ca-amphibole). EPMA investigations evidenced more phases in the preparata with the predominance of the stereomicroscopically determined species for the following minerals: andalusite, apatite (1 case out of 3), glaucophane, corundum, leucoxene (1 case

out of 2), magnetite, colorless epidote and titanomagnetite. Electron microprobe analyses identified multiple phases in the case of hornblende, limonite and limonitic aggregates. The most important correction of misidentification occurred analyzing almandine, antimonite, anthophyllite, dolomite (1 case out of 3), epidote type 2 (yellow epidote), hematite (4 cases out of 6), ilmenite (1 case out of 2), clinozoisite, 'Mg silicate', pyrope and rutile (1 case out of 2). Mixed grains under the stereomicroscope proved to be chemically homogeneous by EPMA but without exact determination of the mineral species in the case of the 'opaque white grains' and the 'rounded, altered mafic silicates'. The 'cinnamon – red' category proved to be colored quartz. Different stereomicroscopic categories of 'amphiboles, pyroxenes, epidotes', 'altered mafic silicates', 'altered, encrusted, rounded, colorless or white silicates', 'cinnamon – blue', 'carbonate' and 'colorless or white, encrusted, altered, rounded silicates' were identified as mineral or lithic fragments with varied chemical compositions (Polgári 1988, 1989, 1990, 1991, Molnár et al. 1989).

Corrections based on the EPMA investigations were denomination earlier pyrope and almandine as general 'garnet' group, earlier anthophyllite as sillimanite, and earlier yellow epidote as staurolite. In the case of samples from Györfalmó, the groups 'anthophyllite' and 'yellow epidote' were 'not determined' in the final reports, however, their presence was still probable and is included in the results of samples from other areas (e.g. point bars of Maros, Molnár et al. 1989).

Misidentifications resulted in quantitative inaccuracies for diopside, 'alkaline amphibole', 'altered pyribole', colorless epidote, clinozoisite, andalusite, topaz, vesuvian, monazite and 'altered undet. grains' (Molnár et al. 1989).

In the final reporting tables these corrections were considered, and the data are presented in an adequate way. Qualitative and semi-quantitative data on the heavy mineral samples is exemplified in **Appendix 2**. Those can be considered as informative data with cautious acceptance of inaccurate mineral identifications mentioned above. This table contains some empty columns due to the correcting procedures. Those remained there for informative purpose and can be deleted during processing the data. It is our future aim to complete the database with new (yet unpublished) data and new samples, which process implies the necessity to insert new mineral species.

Table 1.: List of mineral species checked and corrected by electron microprobe (EMPA) analyses. The third column of the table contains (semi quantitative) percentage values when contaminating species reach significant amount in the ‘monomineralic’ sample. In other cases, the listed contaminating phases are present as a few grains in the prepareate.

1. táblázat: Az elektronmikroszkópás (EPMA) vizsgálatokkal ellenőrzött és korigált ásványfajok listája. A táblázat 3. oszlopában azokban az esetekben szerepelnek százalékos (közelítő) ásvány mennyiségek, amelyekben egy-egy „szennyező” ásvány lényeges mennyiségben volt jelen egy-egy „monomineralikus” preparátumban. A csak felsorolásszerűen megadott ásványok csak egy-egy szennyező szemcse formájában voltak jelen az adott preparátumban.

original (stereomicroscopic) determination of minerals	Sample locality (and type)	EPMA determination of minerals
almandine	Győrzámoly (shallow drilling)	almandine (+ andradite + spessartine)
amphiboles, pyroxenes, epidotes	Tisza, Duna (recent point bars)	diopside (58%), vesuvian? / altered biotite? (16%), Pb-silicate (barisilite?) (10%), quartz (6%), amphibole? (6%), complex grain (albite, muscovite, Ca-rich silicate)
andalusite	Kőrös, Tisza, Duna (recent point bars)	andalusite (50%), quartz (44%), corundum
antimonite	Hernád (recent point bars)	antimon-ochre (altered antimonite)
anthophyllite	Győrzámoly (shallow drilling)	kyanite, topas, andalusite
apatite type 1	Kőrös, Tisza, Duna (recent point bars)	fluoroapatite
apatite type 2	Kőrös, Tisza, Duna (recent point bars)	fluoroapatite (61 %), chloroapatite (17%), sillimanite - kyanite, epidote (clinozoisite), amphibole (tremolite?)
apatite type 3	Kőrös, Tisza, Duna (recent point bars)	fluoroapatite
opaque white grains	Ráckeve (shallow drilling)	heterogeneous grains of similar compositions (Al, Si + varied Ca, small Fe), + rutile
augite	Maros (recent point bars)	augite
brown amphibole	Novaj, Sarmatianformation (quarry)	brown amphibole
biotite	Duna (recent point bars)	biotite (altered)
altered amphibole	Maros (recent point bars)	brown amphibole
altered mafic silicates	Győrzámoly (shallow drilling)	grains of varied compositions with quartz and lithofragments
altered mafic silicates	Maros (recent point bars)	grains of varied compositions with quartz, chlorite and lithofragments
altered, encrusted, rounded, colourless to white silicates	Maros (recent point bars)	grains of varied compositions
zircon	Győrzámoly (shallow drilling)	zircon
diopside	Csákánydoroszló, Rába (recent point bars)	diopside (+muscovite)

original (stereomicroscopic) determination of minerals	Sample locality (and type)	EPMA determination of minerals
diopside augite	Nógrádszakál, Badenien formation (quarry)	diopside or diopside augite (+ilmenite, pumpellyite)
kyanite	Győrzámoly (shallow drilling)	kyanite
kyanite	Csákánydoroszló, Rába (recent point bars)	kyanite (with many inclusions)
dolomite	Győrzámoly (shallow drilling)	dolomite
dolomite	Bódva (recent point bars)	iron-rich carbonates
dolomite?	Jászfényszaru, Zagyva (quarry)	dolomite (+altered chlorite)
epidote type 1 (green epidote)	Győrzámoly (shallow drilling)	epidote
epidote type 2 (yellow epidote)	Győrzámoly (shallow drilling)	not epidote
'cinnamon – blue'	Kőrös (recent point bars)	apatite (59%), zircon (22%), andalusite - kyanite) (11%), quartz (5%), K-feldspar and albite
'cinnamon – red'	Kőrös (recent point bars)	quartz (+ rutile, altered K-feldspar)
ferrohyperstene (ferrosilite)	Nógrádszakál, Badenien formation (quarry)	ferrohyperstene (ferrosilite) (+albite, magnetite)
glaucophane	Hídvégardó, Bódva (recent point bar)	glaucophane (73%), magnetite, amphibole (non-glaucophane), magnetitic lithofragments
glauconite	Tisza (recent point bars)	glauconite
hematite?	Győrzámoly (shallow drilling)	iron-coated quartz (81%), ilmenite, altered mafic silicate
hematite type 1	Kőrös (recent point bars)	not hematite in the most cases
hematite type 2	Tisza (recent point bars)	not hematite in the most cases
hematite type 3	Hernád (recent point bars)	not hematite in the most cases
hematite type 4	Bódva (recent point bars)	iron oxide (hematite), sometimes with Ti and Cr content
hematite type 5	Sajó (recent point bars)	iron oxide (hematite), sometimes with Ti content
hyperstene type 1 (= ferrohyperstene = ferrosilite)	Győrzámoly (shallow drilling)	hyperstene (altered, many inclusions of magnetite, titanomagnetite and ilmenite)
hyperstene type 2 (= common hyperstene)	Győrzámoly (shallow drilling)	hyperstene
hornblende	Győrzámoly (shallow drilling)	grains of varied compositions (Ca, Fe, Ti) (hornblende is possible)
ilmenite	Győrzámoly (shallow drilling)	ilmenite
ilmenite	Kőrös (recent point bars)	rutile (75%), altered amphibole, altered Ti mineral
carbonate	Győrzámoly (shallow drilling)	grains of varied compositions (calcite with small Mg content, zircon, titanite)

original (stereomicroscopic) determination of minerals	Sample locality (and type)	EPMA determination of minerals
clinozoisite?	Győrzámoly (shallow drilling)	epidote (63%), iron oxide? / iron carbonate? (27%), quartz (10%)
chlorite	Duna (recent point bars)	chlorite (alteration product of biotite), altered chlorite, muscovite, complex grains (muscovite, chlorite, rutile)
rounded, altered mafic silicate	Ráckeve (shallow drilling)	grains of homogeneous composition (Al, Si, Ca, Fe)
corundum	Tisza (recent point bars)	corundum (67%), amphibole (20%), sillimanite, rutile
leucoxene? (white-grey)	Győrzámoly (shallow drilling)	leucoxene (sometimes smaller Ti content) (75%), rutile (25%)
leucoxene? (coloured)	Győrzámoly (shallow drilling)	leucoxene (+ quartz)
limonite, limonitic aggregate	Ráckeve (shallow drilling)	grains of varied compositions: limonitic aggregates, limonite-coated quartz or amphibole
magnetite	Győrzámoly (shallow drilling)	magnetite, ilmenite, Cr-containing magnetite, Ti-Mn-containing magnetite, chromite, titanomagnetite
oolitic magnetite	Győrzámoly (shallow drilling)	magnetite
'Mg-silicate'	Homokterenyé, Zagyva (quarry)	undetermined mixture of organic contamination and mineral grains
muscovite	Duna (recent point bars)	muscovite (fresh), muscovite (altered)
oxiamphibole (basaltic amphibole)	Maros (recent point bars)	basaltic amphibole (+ zircon, quartz)
pyrite	Győrzámoly (shallow drilling)	pyrite (+rutile, quartz)
pyrite (yellow, black, biogenic)	Ráckeve (shallow drilling)	pyrite (20% biogenic)
pyrope	Győrzámoly (shallow drilling)	almandine (Ca- and Mn-containing)
rutile	Győrzámoly (shallow drilling)	rutile
rutile	Maros (recent point bars)	not rutile, leucoxene?, other Ti-mineral?
sillimanite - kyanite	Kőrös (recent point bars)	sillimanite – kyanite
sillimanite type 1 (colorless, white, weakly colored)	Ráckeve, Győrzámoly (shallow drilling)	sillimanite (+ K-feldspar, quartz)
sillimanite type 2 (weakly colored)	Ráckeve, Győrzámoly (shallow drilling)	sillimanite
sillimanite type 3 (colored)	Ráckeve, Győrzámoly (shallow drilling)	sillimanite (sometimes with small K and Fe content)
colorless epidote?	Győrzámoly (shallow drilling)	epidote (62%), sillimanite (15%), quartz (23%)

original (stereomicroscopic) determination of minerals	Sample locality (and type)	EPMA determination of minerals
colorless, white, encrusted, altered, rounded silicates	Győrzámoly (shallow drilling)	grains of varied compositions
staurolite	Győrzámoly (shallow drilling)	staurolite
staurolite	Ráckeve (shallow drilling)	staurolite
titanite type 1	Emőd, Sajó-Hernád alluvial cone (quarry)	titanite
titanite type 2	Ipolytarnóc, Ipoly (recent point bar)	titanite (with many radioactive inclusions)
titanomagnetite	Maros (recent point bars)	titanomagnetite (sometimes with Mn content) (70%), complex grains (magnetite-titanomagnetite), Cr-magnetite, altered magnetite
tourmaline	Győrzámoly (shallow drilling)	tourmaline
zoisite	Győrzámoly (shallow drilling)	epidote or zoisite with small Fe content
green amphibole	Győrzámoly (shallow drilling)	Ca-amphiboles
green amphibole	Maros (recent point bars)	Ca-amphibole (actinolite?)

Comments on the archaeometric applications of the micromineralogical collection

The basic purpose of the collection was to provide samples for the project 'The study of the recent and fossil river bars of Hungary' which aimed to get knowledge on the economically exploitable raw materials and the geology (sedimentology, evolution) of the Pannonian Basin. However, the material deposited in the collection and the data on the heavy mineral assemblages of the different regions of the country might be useful for other scientific purposes, like archaeometry. The comparative HM data could be especially important in case of research where archaeological finds made from clastic sediments or sedimentary rocks are investigated.

One of the most abundant archaeological finds made with the application of clastic sediments is ceramic. Provenance analysis of the aplastic constituents (natural or artificially added, silt-sand-gravel-sized grains) in pottery is a common topic in ceramic archaeometry. Especially in case of coarse pottery, aplastic constituents are used to be more specific (mineralogically or chemically) to the raw material than the clayey paste. Thus, the aplastic constituents might be more promising in the provenance studies (Obbágy et al. 2014; Józsa et al. 2016a, 2016b). Since the sand-sized aplastic constituents usually derive from recent alluvial sediments (silt-sand-gravel) or rarely from diagenized sedimentary rocks, their comparison

with the sand-sized grains of HM separata of the micromineralogical collection might have special relevance.

Sandstones were predominantly applied as stone utensils – grindstones, millstones, whetstones, abrasive stones, rubbing stones or molds. Due to the relatively low quality requirements, these stone materials derived from local or regional raw materials (Szakmány & Nagy 2005, Péterdi 2012, 2020, Kürthy et al. 2013). In recent times sandstones became common building material. Occurrences in the Carpathian Basin are widespread and variable. However, the overall mineralogical composition is relatively homogeneous (quartz, feldspars, micas, lithofragments) and the provenance determination by conventional petrographic or geochemical methods is limited. Thus, the HM assemblage can be fundamental characteristic of the provenance indicating the erosional area of the original sand. Although, the micromineralogical collection is dominantly composed of loose, non-diagenetized sediments, it even can provide comparative information on HM spectra of Pannonian age sandstones.

Heavy minerals of clastic raw materials are resistant to physical processes (e.g. mechanical effects, high temperature firing) during the manufacturing of stone tools or pottery, and preserve the original HM spectrum characteristic for the raw material. Provenance study of ceramics or sandstone utensils may get a sensitive method by comparing HM spectra of archaeological finds and

HM samples of the observed region of Hungary. In archaeometric studies using this approach (e.g. Obbágy et al. 2014; Józsa et al. 2016a, 2016b), the comparative raw material samples are collected during small-scale field works and HM separation which requires much time, manpower and financial or laboratory resources. This work can be simplified and accelerated by using the micromineralogical collection, and in many cases it would be the only way to do comparative HM investigations.

To sum up, the micromineralogical collection of the Mining and Geological Survey of Hungary might provide important support to the Hungarian – or even Carpathian Basin-scale – archaeometric research when provenance of sandstone tools, utensils or building stones, and ceramics are under observation. By receiving information on the average HM composition of a specific region (e.g. catchment area of a river) and in comparison with the HM spectra of the archaeological finds, local or non-local origin of the raw material become possible to determine. An application of the results gained from the micromineralogical collection of MBFSZ for the provenance study of archaeological pottery is presented in the work of Szilágyi et al. (2021).

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Appendix 1.: Record on the samples of the micromineralogical collection (completed with samples without heavy mineral separation or which have been lost)

1. melléklet: A gyűjteményben őrzött minták adatai (kiegészítve azokkal a mintavételi helyekkel, illetve mintákkal, amelyekből nem készült nehézasvány-szeparátum, vagy elvesztek)

Appendix 2.: Heavy mineral separata: qualitative and semi-quantitative data. These data are for informal use, some mineral determinations are to be considered with caution (see details in chapter ‘Micromineralogical studies, HM spectra’).

2. melléklet: Nehézasvány-spektrumok: minőségi, illetve félmennyiségi adatok. Az adatok tájékoztató jellegűek, néhány ásványfaj esetében a meghatározásokat is fenntartásokkal kell kezelni (lásd a cikk “Mikromineralógiai vizsgálatok, nehézasvány-spektrumok” fejezetét).

