DISSERTATION

Titel der Dissertation

"Characterisation of Middle European Chert Sources
A Multi Layered Approach to Analysis"

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Dedication

I dedicate this work to the ones that have always supported me, throughout both good and hard times. Although you are not amongst us any more, I will never forget what you have done for me. This is for you, Papa, Opa and Oma. And my Mom, who carries on bravely.

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Curriculum Vitae

BRANDL Michael

Personal data

Date of birth   13.10.1975

Place of Birth   Graz (Austria)

Education

Dec. 2003   1st degree in the studies of Pre- and Early History, University of Vienna: *Experimentelle Nachbildung der anthropomorphen Kleinplastik aus Krems / Stratzing* (instructor: G. Trnka).

June 2005   M.A., Pre- and Early History, University of Vienna: *Silexlagerstätten in der Steiermark* (instructor: G. Trnka).

2007   Starting Ph.D. - research, Pre- and Early History, University of Vienna: *Characterisation of Middle European Chert Sources. A Multi Layered Approach to Analysis* (instructor: G. Trnka).

Most important excavations

2000 –   Old town of Vienna („Wiener Stadtkerngrabungen", Spiegelgasse,
2011   Salvatorgasse, Mautern, Tulln); Willendorf, Wachau, Middle to Upper Palaeolithic.

Surveys and excavations at the basin of Rein (Styria), prehistoric chert mining site, and Repolust Cave (Styria).

Belize (Mesoamerica), Aguada Lagunita Elusiva – provenace studies of chert used for tool production and construction elements.

Research activities

Raw material analysis of knapped stone tools and chert sourcing in the course of several projects, e.g. in **Austria** (Archäologie Koralmbahn, Willendorf II, Krems–Hundsteig, Krems–Wachtberg, Franzhausen, Gobelsburg etc.), **Europe** (France, Italy), the **Mediterranean** (Southeastern Crete, Sitia Peninsula), in **Mesoamerica** (Aguada Lagunita Elusiva, Northern Belize) and recently **South East Asia** (Dan Chang and Kanchanaburi, Thailand).

Employment

2005-2007	*Researcher*, *Field Director*, Archäologie Service (Old town of Vienna, Mautern, Tulln).
2006-2012	*Raw-material Scientist*, Austrian Academy of Sciences (ÖAW): Palaeolithic sites at Krems–Wachtberg and Krems–Hundssteig, Senftenberg, Gobelsburg, Großweikersdorf. Currently guest researcher at the Institute for Mediterranean and Prehistoric Archaeology, Division for Prehistoric Archaeology, ÖAW.
2005-2010	*Tutor*, University of Vienna: Determination of raw materials for stone tools. Excursions to raw material sources in Styria and Lower Austria. Professor: Gerhard Trnka.

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Dec.2009 - Dec. 2012	Coordinator for applied sciences for the PP 05, SfB HiMAT at Innsbruck, Tyrol.
Since Aug. 2010	Member of the international board for terminology questions concerning SiO2- raw materials at the IMA (International Mineralogists Association).
Since Sept. 2010	Active membership of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times.

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Abstract

During the last decades, provenance studies including micropalaeontological investigations and geochemical analysis of chert and flint sources have played a significant role in providing socio-cultural interpretations for archaeological problems. However, much of the current research consists mainly of case studies which have only touched the surface. Restrictions such as the lack of access to necessary laboratory facilities, narrow testing regions and limited sample amounts have stymied broad scale investigations. A systematic approach that has provided replicable results is lacking, therefore a clear methodology for chert and flint sourcing remains elusive.

Pilot projects undertaken at the Prehistoric Commission of the Austrian Academy of Sciences during the last years have shown a clear possibility for successfully sourcing chert and flint through the application of a transdisciplinary, multi-layered approach. This method consists of a tripartite analytical system: Visual (macroscopical), microscopical and petrological/ geochemical. Visual descriptions allow for a preliminary assignment of artifacts to source regions, whereas microscopical investigations rely on comparative studies concerning microfossil inclusions in chert raw materials identifying specific "fauna communities". For geochemical analysis, Laser Ablation-Inductively Coupled-Mass Spectrometry (LA-ICP-MS) was applied. LA-ICP-MS allows for the detection of trace element concentrations in rock materials.

Although each of these methods has been tested individually and proved suitable to a certain degree for chert sourcing, a breakthrough had yet to be achieved. The essential differences between the current research project and preliminary case studies are twofold:

1.) The systematic application of all methods mentioned above creating a "fingerprint" of each source investigated, and 2.) broad regional investigations applying this interdisciplinary approach on some important European sources. Raw material samples were predominantly provided by the Vienna Lithothec (Leader: Gerhard Trnka, Institute for Prehistory, University Vienna). Only a combination of the above mentioned methods and a close interdisciplinary cooperation between various research fields such as archaeology, anthropology, mineralogy, petrology and micropalaeontology was able to produce reliable and replicable results. These results shall form a solid database for the investigation of prehistorically exploited European chert deposits. The study shall provide answers to important socio-anthropological questions and serve as a useful source for archaeologists and natural scientists. Hopefully it will also encourage further research activities.

Zusammenfassung

Innerhalb der letzten Jahrzehnte haben sich Untersuchungen zur Herkunft von Horn- und Feuersteinartefakten („Silex") unter Einbeziehung von mikropaläontologischen und geochemischen Analysemethoden zu einem bedeutenden Faktor in Hinblick auf sozio-kulturelle Interpretationen archäologischer Fragestellungen etabliert. Dennoch waren die meisten aktuellen Fallstudien nicht dazu in der Lage, die Problematik zufriedenstellend zu lösen. Erschwerter oder überhaupt kein Zugang zu notwendigen Laboreinrichtungen, räumlich zu stark begrenzte Untersuchungsgebiete sowie zu kleine Probenmengen für naturwissenschaftliche Analysen haben umfassende Untersuchungen bisher weitgehend verhindert.

Ein systematischer Ansatz, der reproduzierbare Ergebnisse erbracht hätte, ist demzufolge nach wie vor ausständig, und macht die Notwendigkeit einer brauchbaren Methode für die Herkunftsbestimmung von Horn- und Feuerstein im archäologischen Kontext offensichtlich. Pilotstudien an der Prähistorischen Kommission der Österreichischen Akademie der Wissenschaften haben innerhalb der letzten Jahre Möglichkeiten zur erfolgreichen Anwendung eines transdisziplinären, mehrstufigen Systems für Rohmaterial-herkunftsbestimmungen aufgezeigt. Diese Methode besteht aus einem dreiteiligen analytischen Verfahren: Visuelle (makroskopische), mikroskopische und petrologisch/ geochemische Untersuchungen werden darin zu einer intern gewichteten Einheit zusammengeführt. Makroskopische Beschreibungen erlauben eine grobe Zuordnung von Artefakten zu ihren Herkunftsregionen, mikroskopische Untersuchungen sind vor allem auf vergleichende Studien zu Fossileinschlüssen und der Feststellung spezifischer „Fauna-Vergesellschaftungen" in mikrokristallinen SiO_2- Varietäten ausgerichtet. Für geochemische Analysen wird Laser Ablation-induktiv gekoppelte Plasma Massenspektrometrie (LA-ICP-MS) eingesetzt. LA-ICP-MS ist besonders zur Feststellung von Spurenelementsgehalten in Gesteinsmaterial geeignet.

Obwohl jede der angeführten Methoden individuell getestet wurde und zum Teil auch brauchbare Ansätze geliefert hat, ist bislang noch kein Durchbruch für Rohmaterial-herkunftsbestimmungen geglückt. Es existieren zwei wesentliche Unterschiede zwischen dem vorliegenden Projekt und früheren Studien: 1.) Die systematische Anwendung der oben genannten Methoden und Definition eines „Fingerabdrucks" für jede untersuchte Lagerstätte, und 2.) räumlich umfassende Untersuchungen bedeutender europäischer Horn- und Feuersteinlagerstätten unter Anwendung des interdisziplinären Ansatzes. Rohmaterialproben

wurden in erster Linie von der Vienna Lithothec (Leitung: Gerhard Trnka, Institut für Ur- und Frühgeschichte, Universität Wien) zur Verfügung gestellt. Nur die Kombination der erwähnten analytischen Methoden und enge interdisziplinäre Zusammenarbeit zwischen Archäologen, Anthropologen, Mineralogen, Petrologen und Mikropaläontologen konnte letztlich die gewünschten Resultate erzielen. Die vorliegenden Forschungsergebnisse sollen eine solide Datengrundlage zur Erforschung prähistorisch genützter Silexlagerstätten bilden, eine Quelle zur Beantwortung sozialanthropologischer Fragestellungen sowohl für Archäologen wie für Naturwissenschafter, und Ansporn sein für weitere Forschungstätigkeiten in naher Zukunft.

1. Introduction

Chert source provenance studies are a challenging field of interdisciplinary research and have gained a lot of attention in archaeological science. In the course of thorough engagement with prehistorically exploited SiO_2 -rock sources (traditionally referred to as "flint mines"), researchers encountered the limitations of assigning raw materials to their source region. Conventional chert and flint raw material determination mainly concentrated on visual comparison, microscopical analysis or a combination of both methods (e.g., Brooks 1989; Bustillo et al. 2009; Kozłowski 1973; Kozłowski 1991). The main problems with traditional approaches are the considerable similarities of chert raw materials in the macroscopic appearance, most often due to similar geological settings and similar fossil inclusions. Such undistinguishable raw materials were either assigned to very broadly defined source regions showing a high error rate or remained indefinable.

Besides traditional approaches, attempts to generate characteristic "fingerprints" of particular raw materials through trace element analysis have been undertaken repeatedly, but the results fell short of expectations or the analysis was conducted to a very limited extent (e.g., Evans et al. 2007; Hughes et al. 2010; Morgenstein 2006; Roll et al. 2005; Tykot 2004). The main focus of these previous studies lies on North America (Luedtke 1992; Speakman et al. 2002; Morgenstein 2006; Hughes et al. 2010), for Middle Europe this research field is still at the incipient stage (e.g., Bush & Sieveking 1986**;** Halamic et al. 2005; Kasztovszky et al. 2005; Pawlikowski 2008; Přychistal 1994; Sieveking et al. 1972; see also "Research program of the Università degli Studi di Siena 2011"[1]). However, most of the previous chert sourcing studies only included small catchment areas due to various constraints further exacerbating the issue at hand by producing questionable results.

This in mind, the current project especially focussed on statistically relevant amounts of samples to ensure that the data are reliable and comparable to already existing datasets. In the course of years of experience (not withstanding errors along the way), substantial insights concerning raw material determination were compiled.

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[1]Titel: „The raw materials economy in recent prehistory. Archaeological and geochemical research on the mechanisms of procurement of Gargano flint and its circulation in central and southern Italy between the VI and III millennium BC". http://www.ricercaitaliana.it/prin/dettaglio_prin_en-2007YMXNXF.htm; query 01.12.2011

Scientific questions concerning the raw material of stone tools can be condensed into two main focal points:

(1) what is the raw material and,
(2) where does it originate from.

The first step in raw material studies is the accurate determination of all raw materials contained in an archaeological assemblage, such as chert, flint, chalcedony, jasper, etc. Even though the main focus of this thesis is on provenance studies, a classification system for siliceous rock material will be discussed in Chapter 2.

For provenance studies, a multi-layered approach applying a three step model based on macroscopical, microscopical and mineralogical/geochemical investigations was employed. Precise evaluation of every individual step of analysis allowed for the development of a reliable system for the determination of source areas for chert artifacts. The applicability of this "Multi Layered Approach" was tested in the course of three case studies forming the main corpus of the dissertation. Sample material was provided by the Vienna Lithothec (Institute for Prehistory, University of Vienna, directed by Gerhard Trnka). All analysed samples are stored at this research institution and accessible for future investigations.

1.1. Objectives

The main objective of this project was to find a scientific solution for differentiating between raw material sources and apply the results to archaeological finds. This was accomplished by the systematic characterisation, including the application of new compositional methods, of selected chert sources from throughout Europe used for prehistoric and historic raw material procurement and distribution (see *1.2. Chronological and spatial framework*). More specifically, this study applies a clearly structured, comprehensible multi-layered system for chert sourcing, in short MLA. The resulting multidimensional fingerprint shall allow for a differentiation between macroscopically and microscopically similar raw materials. The fusion of these methods provides robust data and information pertaining to lithic raw material provenance. Additional to that, the range of the newly implemented LA-ICP-MS method in raw material science for chipped stone tools will be tested in three specific case studies.

The three case studies chosen for this undertaking involve chert raw materials similar in macroscopic appearance and were therefore predestinated for errors assessing their provenance. The studies were intended to cover a broad range of such raw materials as determined in Section *2.1. Terminology*. The main research issues concerned three raw material groups: Tabular chert, radiolarites and high-quality flint referred to as "silex blond".

As indicated below, the chronological framework of the archaeological material investigated ranges from Middle Palaeolithic chert assemblages over Neolithic complexes to more recent material, specifically gunflints from the Napoleonic period. The analysed chert and flint materials of each respective study are similar in visual aspects but highly different in geological genesis conditions, e.g., age, host rock facies, palaeo-fauna environments, etc., exploring the accuracy of the proposed MLA in practical implication.

1.2. Chronological and spatial framework

Chronology

The chronological framework of the thesis entails a timespan from prehistory to the 18th/19th century. The case studies focus on chert and flint deposits used for prehistoric stone tool production and gunflint manufacturing.

The Palaeolithic components of the dissertation encompass Middle Palaeolithic assemblages from Styrian cave sites such as the Repolust Cave, Tunnel Cave and Zigeuner Cave chert finds and Upper Palaeolithic radiolarite artifacts from the Krems-Wachtberg site.

Neolithic chert artifacts from Styrian and Carinthian hilltop settlements form the central issue of the "tabular chert"-case study.

A chronological outlier regarding the extensive use of chert and flint is presented in the course of a study concerning a gunflint cache from the Neugebäude Palace in Vienna. This substantial assemblage was the foundation of far-reaching investigations on European gunflint industries during the Napoleonic wars, marking the last peak of post-Stone Age silicate utilization.

Spatial: Investigation areas

The area of raw material deposits to be analysed concentrates on Europe (Western, Central and parts of Eastern Europe). Three catchment areas were investigated:

For the tabular chert case study, the focus was laid on Styrian assemblages in comparison with Southern Bavarian tabular chert from Baiersdorf. In the course of those investigations, the chert source at the Rein Basin north of the Styrian capital, Graz, was established as a Neolithic quarrying site, and the origin of the Middle Palaeolithic assemblage from the Repolust Cave could be determined.

The radiolarite study focused on a differentiation between raw materials from the Northern Calcareous Alps and those from the Carpathian Mountains, testing for a possibility of an assignment of radiolarite artifacts from the Gravettian Krems-Wachtberg site in Lower Austria to those source regions.

The gunflint study concentrated on the large scale distribution of a raw material referred to as "silex blond", indicating French market supremacy for gunflints at the end of the 18th century. However, visually similar raw material occurs in Upper Italy, at the Garda Lake source area, and in Poland in the vicinity of Kraków. Together with material from Meusnes, France, these occurrences were included into the comparative study investigating the origin of the major component in the Neugebäude gunflint cache.

1.3. Present state of research

As indicated above, attempts to designate artifacts to source regions date back to the beginnings of archaeological interest in prehistoric "flint mining". Consistently (and with good reason), until today visual and microscopical techniques continue to be the most employed for determination.

By the 1960s, analytical techniques were introduced into chert source provenance studies (e.g., Wright 1967) and commonly applied from the 1970s on (e.g., Luedtke 1978; Luedtke 1979, 746-747; Reed 1990; Tykot 2003; Tykot 2004). The wide range of interdisciplinary approaches has substantially influenced the course of this research field. An overview of the most relevant current methods with selected references is provided in **Table 1.1.**

analytical method		selected reference(s)
abbreviation	**full name**	
XRD	X-ray diffractometry	Malyk-Selivanova et al. 1998
OSL	Optically Stimulated Luminescence	Pooltona et al. 1995
MSM	Magnetic Susceptibility Measurement	Thacker & Ellwood 2002
UVF	Ultraviolet fluorescence analysis	Lyons et al. 2003
	RAMAN-Spectroscopy	Cinta Pinzaru et al. 2008; Olivares et al. 2009
DCAES	Direct Current Arc Emission Spectrophotometry	Hughes et al. 2011
PGAA	Promt Gamma Activation Analysis	Crandell 2012
PIXE	Proton Induced X-ray Emission	Elekes et al. 2000; Pillay 2001
PIGE	Proton Induced Gamma-ray Emission	Elekes et al. 2000
VNIR	Visible/Near-Infrared Reflectance Spectroscopy	Parish 2009
LIBS	Laser Induced Breakdown Spectroscopy	Giakoumaki et al. 2006
XRF	X-ray fluorescence	Pillay 2001; Rafferty et al. 2007; Olivares et al. 2009; Hughes 2010
(I)NAA	(Instrumental) Neutron Activation Analysis	Wright 1967; Aspinall & Feather 1972; Julig 1995; Malyk-Selivanova et al. 1998; Glascock & Speakman 2008
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry	Thompson et al. 1986
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry	Aspinall & Feathers 1972; Pollard et al. 2007, 134
ICP-AAS	Inductively Coupled Atomic Absorption Spectrometry	
LA-ICP-MS	Laser Ablation Inductively Coupled Plasma Mass Spectrometry	Gratuze 1999; Gratuze et al. 2001; Pillay 2001; Speakman et al. 2002; Speakman & Neff 2005; Morgenstein 2006; Evans et al. 2007; Milne et al. 2009 ; Olofsson & Rodushkin 2011

Table 1.1.: Techniques of importance for chert source provenance studies

Graph: M. Brandl.

Visible/Near-Infrared Reflectance Spectroscopy (VNIR) and Laser Induced Breakdown Spectroscopy (LIBS; see **Table 1.1.**) were more recently employed, with VNIR still in the testing phase. However, the main focus is presently laid on three geochemical methods in this research field. These are XRF, NAA (INAA) and LA-ICP-techniques, predominantly LA-ICP-MS. The major discussion is between the application of NAA or one of the LA-ICP methods.

XRF, NAA and the ICP-techniques quantify the specific elemental composition contained in rock material. Concerning chert analysis, the main objective is on the detection of rare earth elements (REE; see Murray et al. 1990; Murray et al. 1991; Murray et al. 1992) and trace elements (Bush 1976; Parish 2009).

In comparison, LA-ICP-MS turned out to be one of the most promising new approaches in chert sourcing. This technique was first applied to lithic sourcing in archaeological contexts in the late 1990s (e.g., Gratuze 1999, Gratuze et al. 2001). Data gained by LA-ICP-MS are well comparable to results from other methods like NAA, X-ray fluorescence and digestion ICP MS (Speakman & Neff 2005). Within the spectrum of this backdrop evolved the research presented here.

2. Material

Investigations conducted in the course of this thesis are confined to SiO_2-raw materials used for knapped stone tools, generally referred to as "silicites" (Přichystal 2010, 178). Genetically, they are non-detrital siliceous rocks, and therefore belong to the group of chemical sedimentary rocks such as limestone. Due to the considerably wide range of SiO_2 modifications, it was decided to strictly focus on organogenic SiO_2-varieties of the chert-group. Since there are no internationally coherent standards, a discussion of the terminological system underpinning the thesis is indispensable.

2.1. Terminology

The determination of raw materials in archaeological contexts is one of the most challenging undertakings in interdisciplinary studies. This is especially true for SiO_2-rocks of the chert group. Presently, the term "chert" is replacing most of the synonyms used by archaeologists for the identification of a wide range of SiO_2-rocks. However, in French and German most SiO_2-varieties are referred to as "Silex".

According to Frondel (1962, 223), *"chert, perhaps originally chirt, is believed to be a local English term that was taken into geological use. It may be of onomatopoeic* (an imitating sound, ed. note) *origin. The name chert may be of more recent origin than flint, and unlike flint, is not found in literary usage. It was well established in meaning in 1679 ..."*

The essential elements of the following implementations were published by Brandl (2010) in the *Archeometriai Műhely-Series* of the Hungarian National Museum as a consequence of the IMA-meeting at Budapest in 2010 (*20th General Meeting of the International Mineralogical Association. Title: Bonds and Bridges: Mineral sciences and their applications*).

2.1.1. Defining chert

Chert is a micro- or cryptocrystalline sedimentary rock material composed of silicon dioxide (SiO_2). *It occurs as nodules, concretionary masses and as layered deposits. Chert breaks with a conchoidal fracture, producing sharp edges. In geological terms flint and chert are the same, with the term "flint" referring to chert found in chalk (Brandl 2010, 183).*

This statement requires further explanations.

The proposed classification system is designed for chert-varieties formed in tethyan genesis environments. The Tethys Ocean – succeeding the Palaeo-Tethys – existed mainly during the Mesozoic and the older Cenozoic period at the eastern shores of the Pangaean supercontinent. At its maximum extension, it stretched along the northeastern (= the emerging Asia) and southeastern (= Eastern Gondwana) coastlines of Pangaea. This roughly correlates with the area between present-day Middle Europe to the east of New Guinea. Along the Pangaean continent, the Tethys Ocean had vast shallow marginal seas, especially in the European regions. In the course of the breaking up of Pangaea into the land masses of Laurasia and

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Gondwana during the Jurassic period, the Tethys expanded towards Europe, converting shallow water zones and previously continental areas into deep-sea basins. During the Cretaceous era, the Tethys was closed off between the remaining parts of Gondwana. These are present-day's Africa and India, drifting to the north-east counterclockwise, and Eurasia drifting clockwise to the south.

Both parts of Pangaea, now Africa and Europe, were situated markedly further to the south than their present position. Thus, tropical and subtropical climatic conditions were prevalent in the Tethys area, producing coral reefs and abundant marine fauna (Tollmann 1984, 93-113). This is the environment of partly extensive chert formation linked to marine sediments, mainly during Jurassic and Cretaceous times.

However, there is chert formation beyond this system. Older non-tethyan cherts are mainly of Precambrian age (e.g., Laschet 1984; Sugitani et al. 2002; Perry & Lefticariu 2003; Knauth & Lowe 2003; Westall et al. 2006). Younger chert formations, predominantly of Neogene age, are known from the Eocene (Houser 1985; Muttoni & Kent 2007) and the Miocene (Brandl et al. 2011; Remincourt et al. 2009; Weiss-Krejci & Brandl 2011, 152). Some of these Neogene (formerly "Tertiary") chert deposits (e.g., Collorgues in southern France and Rein in Styria, Austria) are of lacustrine origin. A brief discussion concerning the genesis of chert varieties from different formation environments and periods is provided in Section 2.2.

2.1.2. Terminological issues

Both archaeologists and mineralogists are concerned with the determination and with provenance studies of rocks used for stone tool production in prehistoric and historic times. Different approaches to such a complex issue must necessarily lead to misunderstandings.

Before analytical techniques concerning the composition of lithic materials can be applied to evaluate systems of lithic raw material procurement of past societies, the most important step is the correct classification of the rock materials. Extensive discussions with colleges from Central and Eastern Europe showed high accordances as well as divergences defining SiO_2-rock materials. A commonly accepted working basis implicates a generally applicable terminology for a determination of such lithic resources. This section provides a practicable

approach to a classification system based on petrological, mineralogical and archaeological demands.

A general overview of lithic materials used for knapped stone tools is provided in Appendix C (**Table AC1***).* Members of the chert-group are highlighted.

According to these primary definitions narrowing down the field of research, members of the chert-group are discussed in detail. A definition of terms used in the system and a characterisation of these rock varieties leads to the final step, a formalized determination system. The basic framework has been developed at the Austrian Academy of Sciences in the course of determining the lithic assemblage from Krems-Hundssteig and Krems-Wachtberg (Brandl and Reiter 2008, 43-49). The high variability of raw materials found in the Upper Palaeolithic sites initiated this approach, extended experience in raw material determination in the course of different projects completed the coherent classification system (e.g., Binsteiner, Ruprechsberger, Brandl et al. 2006; Brandl & Reiter 2008; Brandl 2009; Brandl et al. 2011).

2.1.3. Definition of terms used in the Classification System (categories)

General terms

2.1.3.1. Fissures

Fissures are naturally occurring clefts caused by tectonic activity. They are often filled either with quartz or foreign minerals like calcite (which leads to the well known "vein-structure"). They are characteristic for alpine cherts, which were tectonically stressed imbedded in the carbonatic host rocks.

2.1.3.2. Fracture Properties

Different raw materials display various breaking properties, however they are not necessarily equatable with their knapping properties. "Fracture properties" refer to breaking schemes in general rather than only of those deriving from intentional knapping, although in many cases

they definitely coincide. The knapping properties are always contingent to the general fracture properties, but not vice versa.

Within the chert group, following fracturing features can be noticed:

- Conchoidal-smooth.
- Amorphously-rough.

2.1.3.3. Granularity

The grain size is generally defined by **ISO 14688-1**-standards (BSI 2009, 7; **Table 4.1.** in Chapter *4. Analytical techniques*). In the Classification System for the present dissertation, they range from very rough over coarse to very fine grained. A closer definition is not useful for a general classification, however, for certain varieties a higher resolution has to be applied.

2.1.3.4. Carbonate content

Rocks with silicified matrix originating from limestone or chalk can always contain a certain percentage of carbonate. Calcite and dolomite traces (never exceeding 1 wt.%) are not unusual, however they are never main rock constituents (Graetsch & Grünberg 2012, 34). Carbonate content from calcite inclusions – not from dolomite – reacts with the contact of deluted hydrochloric acid (HCl) foaming up due to escaping CO_2. The degree of the frothing is of course dependable on the amount of carbonate present in the actual sample. Often, the carbonate content is only detectable in the cortex region and in some cases it is only preserved there.

2.1.3.5. Matrix

The term "matrix" defines the general rock constituents of lithic raw materials. This is the basic composition of a mineral or a rock.

Orthosilicic acid forms the cementing material of silicified rocks emerging from carbonatic bedrock. In the course of extensive XRD-analyses on chert, flint and other microcrystalline SiO2-modifications, Graetsch & Grünberg (2012, 34) determined that chalcedony is the predominant variety in the rock matrix.

A certain granularity is discernable in the matrix of most of those rocks, especially in alpine cherts or in silicified limestone. In many cases the material is very fine grained and the granularity is not perceptible at all (like in Baltic flint). This fact mostly coincides with a high homogeneity of these raw materials.

2.1.3.6. Inclusions

2.1.3.6.1. Fossil inclusions

Fossil inclusions only occur in rocks, they are never present at minerals. Micropalaeontology (see Chapter 4) is an especially important tool for the determination of biogenic rocks. In tethyan sedimentary genesis environments, the following fauna remains are common and can be identified (depending on preservation conditions).

Radiolaria

Radiolarians are marine protozoans of the order Radiolaria, displaying rigid siliceous skeletons and spicules **(Fig. 2.2.)**. Radiolarians occur almost exclusively in the open ocean as part of the plankton community. Their skeletons occur abundantly in ocean sediments. Two important super-orders can be distinguished within the Radiolarian class, Triptylea and Polycystina. Only the latter form skeletons composed of pure opal. Therefore they are more resistant to dissolution in seawater and typically found in the fossil record. Polycystina may be divided into two suborders, the Spumellaria displaying a spheric shape and the Nasselaria with different, non-spheric shapes (**Fig. 2.1.**; MIRACLE 2013).
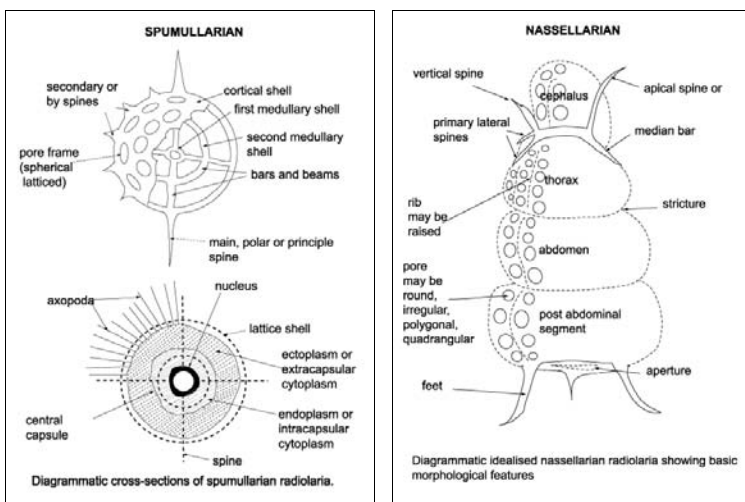
Fig. 2.1.: Schematic drawing of Spumellaria and Nassellaria type radiolarians

Graph: MIRACLE.
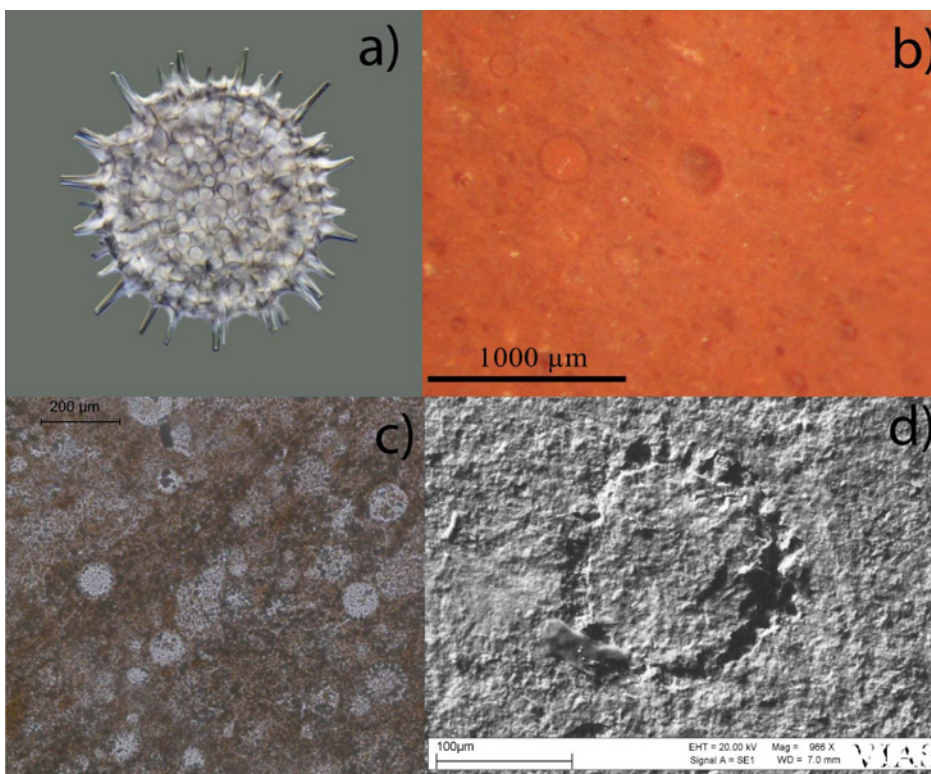
Fig. 2.2.: Radiolaria

a) living radiolarian, Mediterranean Sea
(http://www.mikro-foto.de/ query 10.3.2013)

b) radiolarite: reflected light microscopy (Grubalacke, Tyrol)
(M. Brandl);

c) radiolarite: thin section (Grubalacke, Tyrol)
(M. Brandl/ P. Tropper);

d) radiolarite: SEM-picture (Grubalacke, Tyrol)
(M. Mehofer).

Sponge remains

Most of the sponge remains found in cherts are members of the class *Demospongiae* (phylum *Porifera*). Their skeletons consist of the fibers of spongin, a protein, and spicula ("skeletal needles"; **Fig. 2.4.**). Some sponges either consist entirely of spongin or of spicula. The spongin basically binds the spicula; if there are no spicula present, the skeleton is articulated with very dense fibres of spongin. In cherts, parts of sponges in every stage of preservation can be included, even entire "body parts" are preserved in rare cases **(Fig. 2.3.)**.
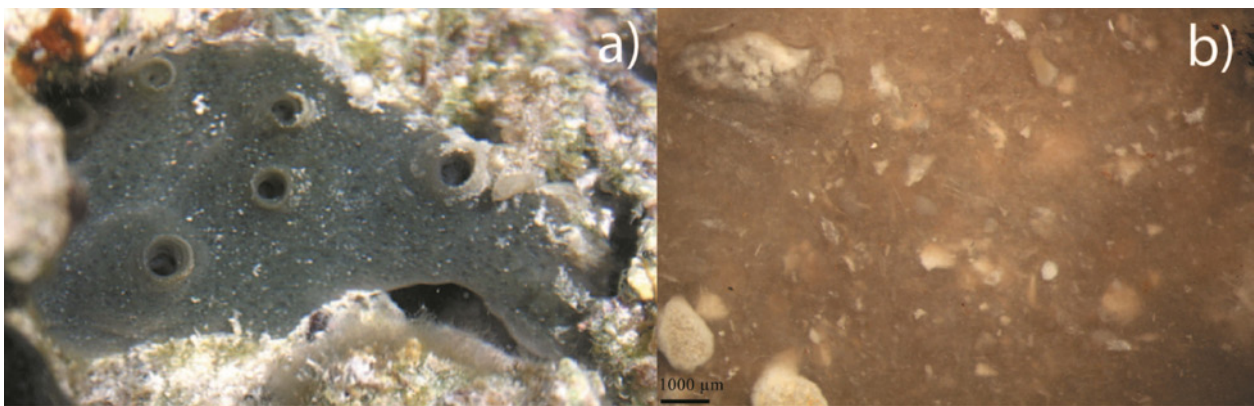
Fig. 2.3.: Marine sponges

a: *Amphimedon queenslandica*, a marine sponge;
b: sponge tissue in Kraków "flint"

Photos: a: MichaK at <u>http://www.wissenschaft.de/wissenschaft/hintergrund/311706.html</u>
        b: M. Brandl.

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Spicula

Spicula are pointed structures serving as a skeletal element in various marine and freshwater invertebrates. In most cases, they are the skeletal needles originating from marine sponges (*Demospongiae*), consisting of silica **(Fig. 2.4.)**.
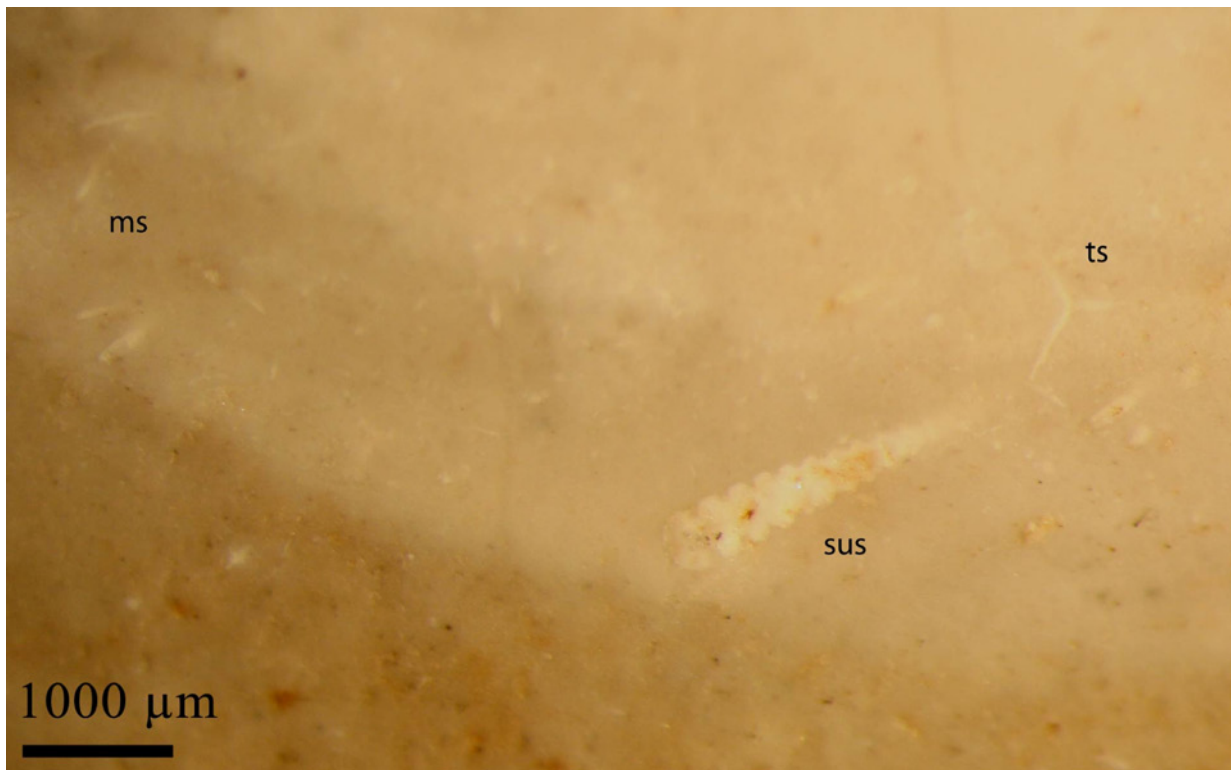
Fig. 2.4.: Spicula in chert (artifact, Krems Wachtberg, WA 3736)

Key: ms: monaxon spicula;
ts: triactine spicula;
sus: sea urchin spine

Photo: M. Brandl.

Crinoidea

Crinoids, also known as "sea lilies" or "feather-stars", are marine animals that form the class *Crinoidea* of the *echinoderms*. They can occur in both, shallow water and deep sea environments. Crinoids are characterized by a mouth on the top surface which is surrounded by several feeding arms **(Fig. 2.5. a)**. Usually they have a stem attached to a substrate. In most cases only the wheel-like joints of the stem of the fossil crinoidea, the so called "trochites", are preserved in cherts **(Fig. 2.5. b)**, forming rectangular shaped inclusions in the rock matrix **(Fig. 2.5. c)**.

Fig. 2.5.: Crinoidea

a: fossil crinoidea, Northern Germany;

b: trochites in the cortex of Baiersdorf chert (G);

c: trochite inclusions in flint (Waabs-Hökholz, G)

Photos: a: fossile-seelilie_Norddeutschland 2005 GNU Free Doc. License by Berengi 2013;

b: M. Brandl;

c: G. Trnka.

Foraminifera

Foraminifera ("hole bearers") or forams are marine microorganisms forming a large group of amoeboid protists with reticulating pseudopods. They typically produce a test, or shell, which can have either one or multiple chambers, some of which display quite elaborate structures **(Fig. 2.6.)**. These shells are constituted from calcium carbonate ($CaCO_3$) or agglutinated sediment particles. Foraminifera are most commonly found in cretaceous sediments containing siliceous rocks.
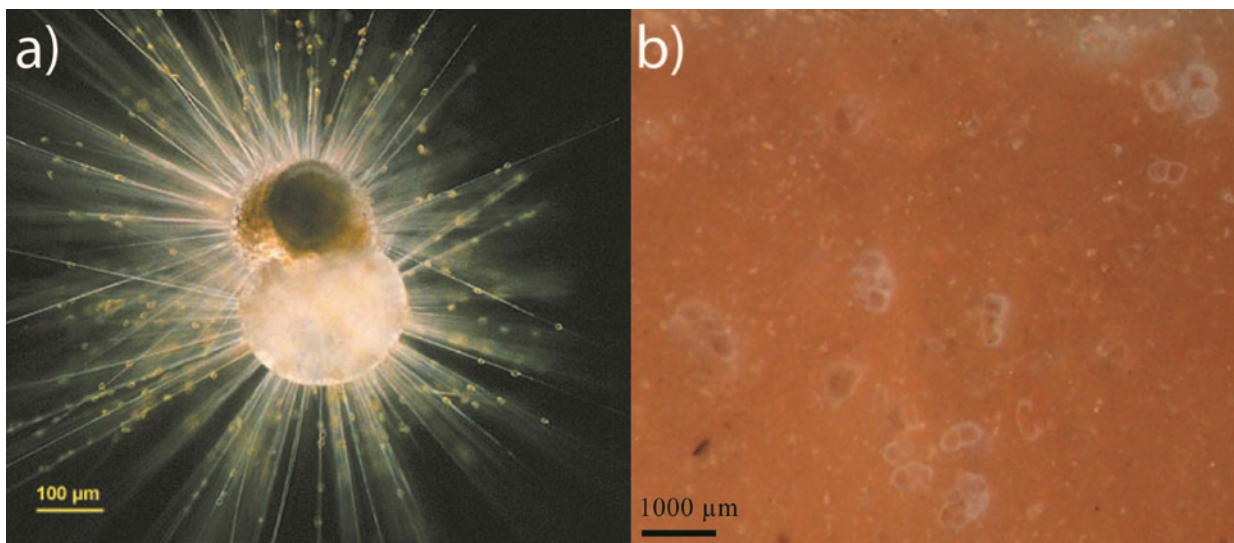
Fig. 2.6.: Foraminifera

a: Benthic foraminifer of the *Globigerinoides* species
b: Cross section of a foram (*Globotruncana* species) from Passo Preadia, Val di Non, Trentino (IT), cretaceous, Biancone formation

Photos: a: O.R. Anderson, at http://serc.carleton.edu/microbelife/topics/proxies/paleoclimate.html
b: M. Brandl.

Additional fossil inclusions

Additional to those, other characteristic fossil inclusions can be distinguished in varieties of the chert group. Bryozoa, diatoms, echinoderm remains (e.g., sea urchin spines), skeletal remains of various marine creatures, seashells of all different kinds, algae and detritus are common inclusions in chert and flint and complete the spectrum of possible tethyan fossil remains **(Fig. 2.7.)**.
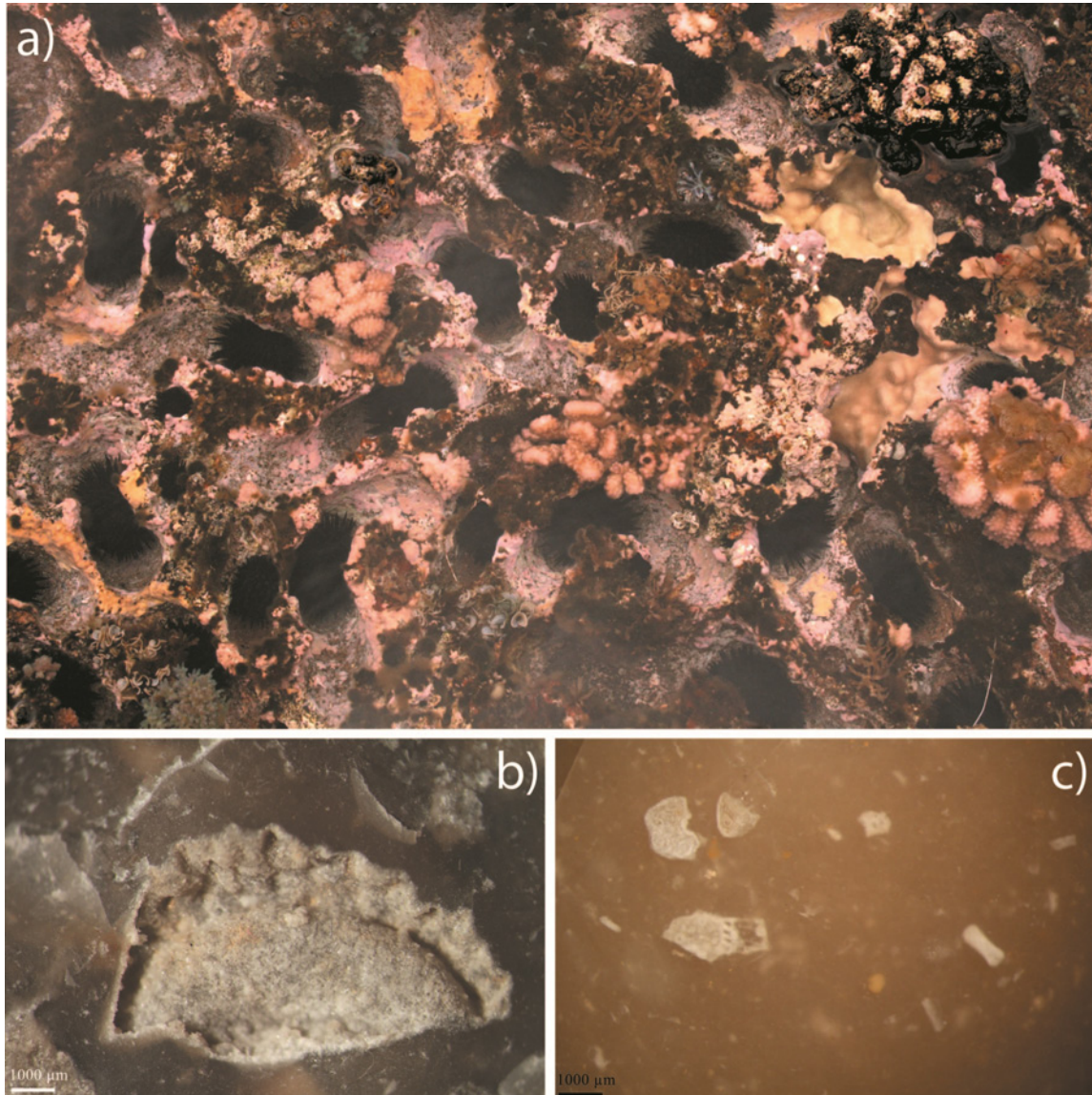
Fig. 2.7.: Reef fauna community and examples of different fossil inclusions

a: reef fauna community in a tide pool, Oahu, Hawaii;

b: seashell inclusion (Kraków "flint");

c: echinoderm remains (Meusnes flint)

Photos: M. Brandl.

2.1.3.6.2. Non-fossil inclusions

The most abundant non-fossil inclusions in silicites are heavy minerals like garnet, tourmaline, rutile, ilmenite, cassiterite, etc. Some chert varieties contain certain amounts of mica. Quartz geodes and SiO_2-precipitations are common non-fossil inclusions as well, the precipitations can show a high variation in colour range **(Fig. 2.8.)**. In most cases, a closer determination of foreign minerals contained in siliceous rocks can only be achieved accurately by applying mineralogical/geochemical analysis.
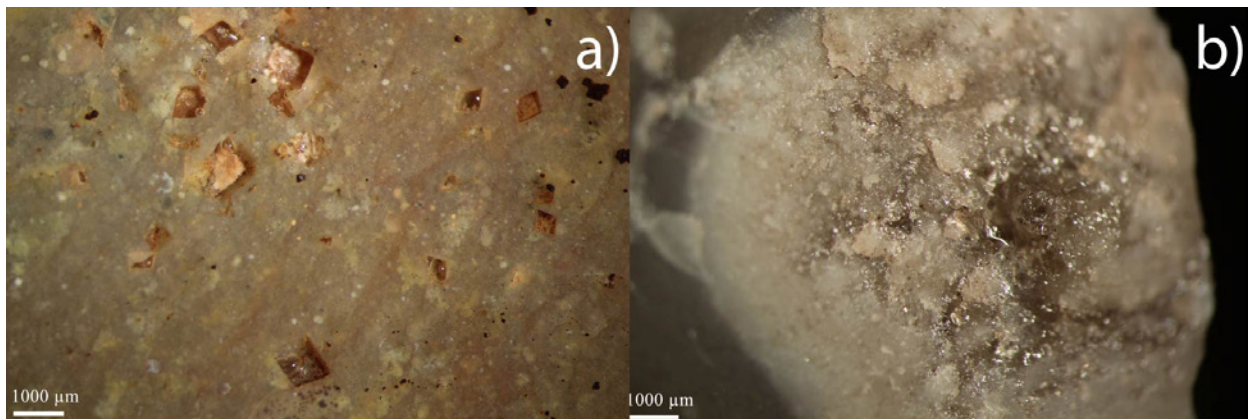
Fig. 2.8.: Different non-fossil inclusions

a: trigonale crystal cavities (Vienna Gemeindeberg);
b: geode in chert (Kraków "flint")

Photos: M. Brandl.

2.1.4. Definition of raw materials of the chert group

2.1.4.1. Chert

In the broad sense, every sedimentary SiO_2-rock (siliceous rocks) formed by means of mainly biochemical processes can be referred to as "chert" (see above). Accordingly, the rock matrix is primarily built from fossilized microorganisms. Regarding the geological genesis, the chert group is subdivided into chert and flint, with chert formed during the Jurassic age and flint during the Cretaceous period.

In that sense, chert is closer defined as "Jurassic chert". Taking into account that other SiO_2-rocks of Cretaceous age exist besides the "sensu stricto flint", the term "Cretaceous chert" is a compromise for such raw materials.

Generally, the matrix of chert is silicified and contains fossil inclusions in most cases. Such inclusions are commonly employed to define chert closer. Predominating microfossils are used to create subvarieties in the chert-group, such as radiolarite, spiculite or spongiolite (spongilite). Characterising these varieties, researchers concerned with raw material description are facing a terminology problem. Usually these subvarieties are defined depending on the percentage of microfossils included in the material. Scientists with different research background apply these characterisations to cherts with ratios of 30%, 50% or even 70% fossils of one kind visible under the microscope (see **Fig. 2.9.**). That causes misunderstandings in international discussions and falsifies interpretation models of archaeological assemblages.

A solution of this problem might be a definition according to an **index fossil**, which defines a rock of the chert-group as a **radiolarite**, a **spiculite** or a **spongiolite** regardless of rating percentages. An accurate a priori valuating of international standard is barely achievable and highly prone to errors.

2.1.4.2. Flint

Basically, every silicified rock concretion of cretaceous age can be defined as flint, in the narrow sense "flint" refers to Baltic- respectively Northern European deposits in chalk - context only. The surface of flint is very smooth and satiny when fractured and has in most cases no recognisable granularity. The material can contain a high amount of fossil inclusions, some of them can be of excellent preservation and useful for a determination. Due to the

genesis in commonly soft environments, alpine fissures are rare, which makes the material preferable for stone tool production. Typical alteration ("patination"), caused by surface changing processes, creates a whitish-blue coloration (compare Section 2.4.).

2.1.4.3. Silicified limestone

This rock material is very similar to chert and occurs in the same geological contexts. Silicified limestone typically contains the same fossil inclusions than the host rock facies. In order to distinguish chert from silicified limestone, some testing methods have to be applied. In some cases the high similarity forces a combination of several methods. In many cases, the scratch test using a steel needle shows the difference in the scratch pattern. Best results can be achieved applying the carbonate test using HCl; silicified limestone holds carbonatic remains in all cases. Calcite surfaces in the rock matrix scattering the light of the reflected light microscope are further indicators.

2.1.4.4. Lydite ("Flinty slate")

Lydite is a slight metamorphic, mostly thin layered siliceous rock with a dense, slated structure. In most cases the colour is black due to organic substances. The metamorphosis usually causes the destruction of the fossil remains in the rock material, so that fossil inclusions are barely visible under the microscope.

2.1.4.5. A case in point: Alpine radiolarite
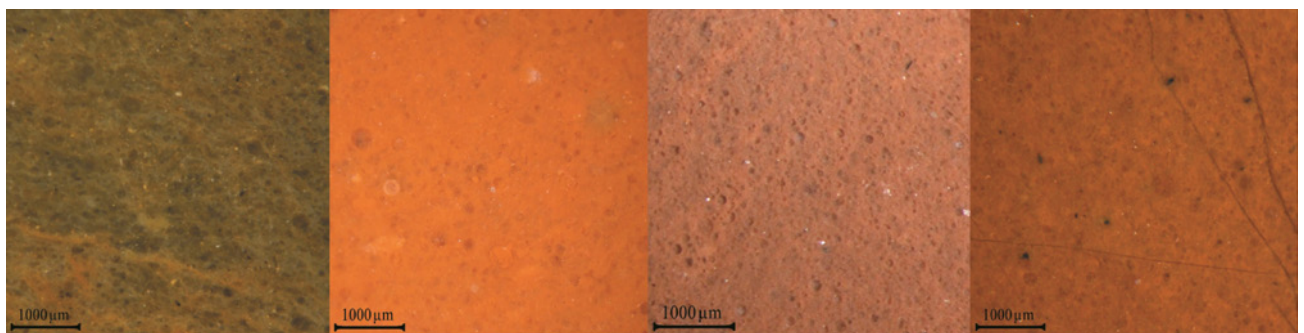
1. Feuersteinmähder, Vorarlberg	2. Grubalacke Northern Tyrol	3. Rothornjoch, Allgäuer Alps Northern Tyrol	4. Rothornjoch, Allgäuer Alps Northern Tyrol

Fig. 2.9.: Micropictures of alpine "radiolarites"

Micropictures: M. Brandl.

Depending on the definition based on the percentage of included microfossils, not all shown examples in **Fig. 2.9.** would be determined as "radiolarites". The chert banks of the Rothornjoch (No. 3 and 4) barely carry more than 50% radiolarian in the visible spot under the reflected light microscope (20x magnification). And there is more to it: From experience, every raw material scientist is aware of the effect that fossils occur concentrated in certain parts of chert banks, whereas other parts lack those inclusions almost completely. Particularly in nodular cherts this can be easily observed at areas close to the cortex, where fossil remains accumulate.

In the course of refitting archaeological artifacts, two raw material varieties coalescing in one chert nodule can emerge. The author has experienced this phenomenon himself, when a chert (without any visible inclusions at all) and a radiolarite (with approximately over 50% radiolarian content) matched perfectly.

This underlines the urgent needs of a terminological system that is at the same time easy to handle and produces accurate results. Of course not every insecurity in raw material detection will be clarified applying the proposed Classification System, however, accuracy will definitely increase with strict adherence to it.

2.1.5. Guide to the usage of the Chert Group Classification System (see Appendix C, Tables AC 2 and AC 3)

All parameters defined above are evaluated in the Chert Group Classification System. The categories which are typical for members of the chert-group are itemized in the tables according to their relevance for raw material analysis. The system is structured in the form of a multiple choice model, the majority of positive matches define the questionable affiliation of sedimentary, biogenic SiO_2 raw materials.

2.2. Genesis of chert and flint

The source material for chert and flint formation is SiO_2. The main research questions regarding the genesis of chert and flint concern the sources of chert-forming silica. As mentioned in Section 2.1., there are different genesis environments for microcrystalline SiO_2-

varieties referred to as "chert". Accordingly, these differences promote variation in the formation conditions.

2.2.1. Marine tethyan cherts

Most researchers assign the origin of silica mainly to biogene production (e.g., skeletal opal) and volcano-genetic processes, with the former prevailing. Although volcanic glasses are converted into clay minerals and zeoliths such as smectite and phillipsite during diagenesis, the formation of chert is not necessarily a consequence. In the course of the Deep See Drilling Project, many open questions concerning diagenesis ranging from the original sediments via meta-stabile products of conversion to aged chert could be answered (Bechter et al. 2010, 25).

For the diagenesis of marine sediments, four controlling factors can be determined: Temperature (T), burial depth (z), age (a) and the host rock facies (Murata & Larson 1975). Following the general scheme noncrystalline opal-A $\rightarrow$ microcrystalline opal-CT & opal-C $\rightarrow$ quartz (Graetsch & Grünberg 2012, 20), the diagenesis of biogenic sediments starts with the dissolution of the organic remains caused by pressure. Under the influence of time and temperature, recrystallisation processes form amorphous opal-A, a SiO_2 modification rich in water ("skeletal opal"). In the course of dissolution processes, opal-A is transformed into crystalline opal-CT, producing small globules of ca. 5 µm in size, so-called lepispheres (Calvert 1974). The transformation of opal-A into opal-CT in aged cherts depends on time, burial depth and temperature. In the course of the aging of microcrystalline SiO_2-modifications, the coarseness of the microstructure increases and eventually recrystallizes into macroscopic quartz, which indicates the initial stages of rock metamorphosis (Graetsch & Grünberg 2012, 20).

Further considerable factors for the genesis of chert and flint are the chemistry of the pore fluid, the pH-value of the environment, the presence of clay minerals and the amount of organic material. Von Rad (1974, 1025-1036) emphasises the importance of genesis environments for rock forming processes, stating that a transformation of opal-CT into α-quartz happens much faster in a calcareous milieu than in a clayish environment. The recrystallisation of fossil remains such as radiolarian shells (which is directly connected to the preservation of the shells in the rock matrix) is significantly limited in sediments showing a

high clay (smectite) content and in carbonates (Ozsvárt 2008). In the course of diagenesis, porosity decreases accompanied by compaction of the rock material and simultaneous dissolution (Murray 1994; Bechter et al. 2010, 25).

2.2.2. Non-tethyan cherts

However, microfossils are not always the primary sources of silica in cherts as demonstrated by Laschet (1984, 271-272). This is especially true for the sometimes massive Precambrian chert deposits independent of thetyan formation environments.
Laschet (1984, 260) distinguishes between primary and secondary chert formations, separating primary non-detrital siliceous deposits and secondary silicified organic or inorganic material. Two main types of silicification can be observed:
1. impregnation of a sediment or rock by silica-cement;
2. replacement of a sediment or rock by silica (forming chert nodules or banks in carbonates).

For both, secondary and primary cherts, Laschet (1984, 257) proposed a different genesis model emphasising the relationship between opal- and quartz-silica phases. He suggests an origin of (quartz-) cherts from opaline precursors, interpreting the diagenetic opal $\rightarrow$ quartz transformation as a solid $\rightarrow$ solid conversion. Silica units are reorganised in the course of recrystallization processes, which require no intermediate solution step.

Following this model, the main factors controlling solution and precipitation of silica are pH, temperature, the presence of CO_2 and water turbulence. The predominant silica source for primary and secondary cherts is not attributed to biogenic silica, as chert formation can occur in environments lacking evidence for bioproductivity. Volcanic and other subordinate silica sources are also not considered as main suppliers of dissolved silica for extensive chert formation, since most chert deposits cannot be linked to volcanic activities, particularly secondary cherts in carbonates. According to Laschet (1984, 257), the main contributing silica source initiating chert formation is dissolved silica deriving from continental chemical weathering. The rate of silica input into chert forming environments is regulated by extensive global palaeoclimatic zones with ferralitic (= humid tropical, ed. note) weathering.

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2.2.3. Lacustrine cherts

Lacustrine cherts are predominantly formed in brackish or freshwater basin environments. Sources of silica for such micro- and cryptocrystalline SiO_2-modifications can vary significantly, and so do the processes of their genesis. Lacustrine chert can form as a post-depositional silification product of volcanic ashes or tuffs, evaporates or freshwater chalk in lakes or freshwater basins (Houser 1985; Brandl et al. 2011, 57) or precipitate as a result of influx of low pH-water intermixed with silica-saturated solutions, e.g., in coastal depressions (Umeda 2003).

Generally, silica precipitation and diagenesis can evolve very similar to the formation of marine chert, however some processes in lacustrine chertification are still not understood to a full extent due to the diversity of possible geological settings hosting such chert deposits. The first case study presented at this dissertation, Rein versus Baiersdorf tabular chert, provides a more detailed discussion concerning a lacustrine chert deposit at the Rein Basin in Styria, Austria (see Chapter 5.1.).

2.3. Microstructure of chert and flint

Micheelsen (1966) analysed the composition and structure of Danish flint in detail. He determined anhedral flint grains ranging from 2 to 30 μm in size, with a mean diameter of 7,5 μm as the chief components of the flint. They exhibit a random orientation in the rock matrix. Every flint grain consists of a pile of quartz-plates. Every single plate can reach up to 3 μm in diameter and 59 nm thickness and occasionally display a hexagonal circumscription. The plates – twinned according to the Brazil law – are comprised of subgrains of 30-90 nm in diameter. These subgrains are divided by twin faults, producing a twinning effect perpendicular to the planes of the plates and corresponding to the Dauphiné law. This creates a pseudo-hexagonal symmetry of the plates. Accordingly, the subgrains are constituted of twinned right- and left-handed α-quartz. Imbedded between the parallel planes of the plates is a monolayer of H_2O (Micheelsen 1966, 360).

Additional to those findings, Rottländer (1975, 108) observed that the flint grains described by Micheelsen build up into a structure of a higher order, so-called flakes or scales. The

planes of these scales are approximately parallel aligned with a size of up to 50 μm, however their general distribution is random.

Hence, the structural elements of flint are the following starting from the smallest:

1. Subgrains   (30-90 nm)
2. Plates   (3 μm)
3. Grains   (2-30 μm)
4. Scales   (-50 μm)

Concerning the genesis of the main constituents of the flint, the grains, Micheelsen notes: *"It seems plausible that the flint grains have been formed by epitaxial replacement of the fine-grained "subsidiary cryptocrystalline silica" found in many Danish flint nodules"* (Micheelsen 1966, 286).

While Micheelsen confined his analysis to flint, Rottländer investigated alpine chert and chalcedony as well. He found identical structural elements down to the grains, the smaller elements (e.g., plates) deviated in different SiO_2-modifications. Chert displayed a coarser microstructure than flint, whereas chalcedony was finer-grained (Rottländer 1983, 556-557). According to Rottländer (1975, 108), patination of chert and flint (compare Section 2.3.) starts at the boundaries of the scales and loosens the inter-scale connections, which results in the intensification of light scattering. This phenomenon is optically perceived as the "white patina"-effect.

2.4. Geochemistry of chert and flint

Modifications of quartz are very pure substances and contain up to 100 wt% SiO_2. The total concentration of trace elements typically ranges between 200-500 ppm in chert and flint materials. As reported by Rottländer & Weymouth (1980, 35), inclusions such as foreign cations (ions with a positive charge) adhere to the exterior planes of the chert/flint grains and occupy the space between the parallel aligned plates described above.

The trace element content in silicites can be explained by the following geochemical processes:

(1) **substitution** of Si in the crystal lattice by other cations (Faure 1998, 99-111)
(2) **deposition** of chemical elements in pore spaces (Milliken 2003, 214-218)
(3) **inclusion** of foreign minerals in chert/flint.

Ad 1: The substitution of Si^{4+} in the crystal lattice of SiO_2 modifications by other cations is limited to ions with a similar ion radius and charge, such as Al^{3+}, Ti^{4+}, Ge^{4+}, Fe^{3+} and P^{5+} (HFS-elements). A charge difference of 1 is also possible, but requires additional cations or crystal defects to achieve neutrality.

Ad 2: In the case of Al^{3+} and Fe^{3+}, additional cations such as Li^+, Na^+, H^+, and K^+ (LIL-elements) may occupy interstitial positions in the lattice. Trace elements can be deposited in pore spaces cogenetically during the sedimentation processes or secondary in the course of diagenesis. Surface alteration processes like weathering can change the chemical composition by either removal of elements or a secondary deposition.

Ad 3: Synsedimentary inclusion of foreign minerals commonly involves feldspar, carbonates and heavy-minerals (minerals with a density over 2,9 g/cm^3, e.g., rutile, hematite, limonite, etc). They presence of e.g., Ca, Al, Fe, Mn, Ni and Cr can be assigned to such foreign inclusion minerals.

Correlations with Calcium (Ca)
In order to evaluate the origin of trace elements in chert and flint samples for the following case studies, several elements were plotted against Ca. The element Ca usually occurs in chert and flint as inclusion minerals such as calcite, dolomite, or plagioclase and clay minerals. Thus, Ca correlation plots are used in order to render systematic trends related to those inclusion minerals visible.

2.5. Alteration of chert and flint artifacts

There are several phenomena described as weathering or patination, which effect chert and flint, e.g., gloss patination, white patina, stain patina, or desert varnish (Howard 2002, 283-284). Luedtke (1992, 98) describes two different types of weathering that are closely interrelated, chemical and mechanical. Frost fracturaing is the most common type of mechanical weathering. Chemical weathering occurs in the course of the precipitation of soluble materials from the surface regions of chert (Rottländer 1975, 109-110).

Rottländer (1975) focuses on the two main types of chemical patination regularly occuring with microcrystalline quartz varieties: The white and the glossy patination.
In the case of glossy patination, the entire rock surface is covered by a translucent gloss as result of silica deposition. The silica comes from the chert itself, dissolved from projections on the surface and redeposited in low areas uniformly coating the chert (Rottländer 1975; Luedtke 1992).
For white patination, Rottländer (1975, 107) states:
"Alkaline solutions with a pH-value above 10.0 result in white patination. These vigorously acting solvents attack the surface of chert starting at boundaries of grains at the size of only a few mymeter in magnitude. From those microfissures, a solvent penetrates into the material producing etched holes during the process of the patination. Intensity and rate of the patination is directly linked to the microstructure of the raw material."
Fundamentally, research results indicate that silica is removed from the surface of cherts buried in alkaline environments (Luedtke 1992, 99-100).

A commonly recognized form of patination concerns a phenomenon paraphrased as "chert pest" (Brandl et al. 2011, 59). Most likely due to depositional circumstances, such pieces superficially show a compact surface structure, but are tangibly too light for typical chert. In the case of fractures at the edges of these artifacts, it is obvious that the rock structure has been transformed (weathered?) into a chalk-like state, scratchable with the fingernail. Mineralogically, it is still quartz. This corresponds to previous observations concerning the patination of flint (Schmalz 1960; Rottländer 1989).

In such cases a combination of both glossy and white patination needs to be considered. It is not clear, if and how they are interrelated, or if those phenomena occur independently. This

seems rather unlikely due to the fact that artifacts showing a strong glossy effect on the surface are often more porous at the inner parts than others. This was observed at objects showing edge damages, e.g., caused during an excavation or at surface finds. Presence of moisture additionally triggers chemical reactions causing patination on chert surfaces (Burronia et al. 2002, 1281-1282). Some researchers emphasize a direct link between patination to environmental influences, e.g., lichens (Ackerman 1964, 386-387; Rottländer 1983, 560-561; Burroni et al. 2002, 1281).

3. Theoretical implications

The socio-anthropological perspectives of chert source provenance studies are numerous and of great importance for archaeological research (e.g., Dobosi 1991; Edmonds 1995; Odell 1996; Ramos-Millán & Bustillo 1997; Della Casa 1999; Wright 1999; Barfield 2003; Burnez-Lanotte 2003; Lech 2003; Pawlikowski 2008). This dissertation is not focussed on socio-anthropological theory concerning raw material procurement, however, some widely accepted theoretical models will be briefly discussed to provide a backdrop and demonstrate the relevance of the proposed MLA to archaeological science.

The MLA extends into both, prehistory and history. Two of the case studies explore Palaeolithic and Neolithic stone tool assemblages, whereas the third study is concerned with Napoleonic gunflint manufacturing.

3.1. Prehistory

Due to the lack of historical sources like written documents, chipped stone artifacts are amongst the few keys to prehistoric cultures. Regarding the importance of stone tools in prehistoric societies, Sillitoe & Hardy (2003, 563) make a point in stating: *"Clues to the relative importance of stone lie in a detailed understanding of the local resource base, evidence for subsistence strategies and the types of tools found."*

Lithic provenance studies in an archaeological context are mainly concerned with the identification of the presence (and consequently the use) of local versus non-local raw

materials ("exotic materials"). The most frequent research questions examine interaction between communities, transfer of knowledge and goods, early patterns of exchange and the use of certain raw materials as "expedient" or "formal" tools depending on the raw material properties or certain preferences due to multiple reasons. Diverging theoretical models consider whether or not the raw material composition in lithic assemblages represents meaningful human behaviour.

3.1.1. Palaeolithic raw material procurement

For hunter-gatherer societies, many theories seek to explain the compositional patterns of lithic assemblages. Recently, central-place foraging theories and a model referred to as "diet breadth model" gained major importance in Palaeolithic research.

Central-place foraging models require comparisons involving discrete distances between raw material deposits and transport destinations (Beck et al. 2002). They are only successfully applicable if the source of distinct raw materials contained in a lithic assemblage can be identified. Such theoretical models are mainly employed in the case of exploited primary and residual raw material deposits.

The diet breadth – or resource choice – model (DBM) is suitable for the assessment of local and secondary raw material deposits. The model is described in detail by Winterhalder & Goland (1997, 128-134), originally developed for determining efficiency in subsistence patterns of hunter-gatherer groups. However, there are specific aspects concerning lithic resources; Minichillo (2006, 363) explored two main factors: The DBM assumes a *"fine-grained random distribution of resources in the local environment"*. Furthermore, raw material quantities within archaeological assemblages are assumed to represent resource density, separating search time from processing and handling efforts. For secondary and residual surface deposits, handling and processing costs are assumed to be nearly equal, leaving search time as the main cost.

Additional to that, Wilson (2007) evaluates the attractiveness of lithic resources depending on qualitative and quantitative criteria, as well as, topographical considerations (i.e. accessibility of the source). This approach became known as "Gravity Model".

In the course of recognising "raw material economics in their environmental context", Wilson (2011, 174) states:

"In reconstructing past human lifestyles, resources should be defined and qualified in terms of human use. A rock is not just a rock: it is more or less suitable as a raw material for tool-making. The slope of the terrain is not just an angle: it requires more or less energy for humans to walk up or down it…(). Furthermore, it is important to pay attention to scale. People live on a relatively small scale of landscape. Water may be obtained from a spring that measures a few metres across, rocks from an outcrop that is not much bigger. Adding in the complexity of human behaviour makes the job even more difficult."

A different approach has been proposed by Brantingham (2003). His "neutral model" (NM) is based on the argument that raw material type and abundance are irrelevant for hunter-gatherer lithic material procurement strategies. The NM attributes the presence of certain kinds of raw materials in Palaeolithic assemblages to random encounters with lithic sources and the amount of available space in the mobile tool kit, rather than planned lithic procurement expeditions ("random-walk foraging strategy"). Optimization, depth of planning and risk management can only be assumed in cases where lithic assemblages reveal patterns deviating from the "neutral baseline expectations" (Brantingham 2003, 487-506).

3.1.2. Neolithic raw material procurement, exploitation and distribution

Discussions concerning Neolithic raw material procurement and the explanation of displacement of raw materials consequently involve more complex models. Neolithic groups were in most cases (at least partly) sedentary and possessed knowledge of mining techniques for lithic raw materials since the Early Neolithic period. Thus, profoundly different economical systems than in Palaeolithic times have to be assumed.

In addition to "conventional" raw material procurement – i.e. collecting and digging of shallow pits for extraction – the mining of lithic raw materials was carried out by digging shafts, sometimes over 10 m in depth. This does not necessarily implicate a highly sophisticated knowledge, as has been observed in ethno-historic and even contemporary examples (e.g., rock-crystal mining at Minas Gerais, Brazil, **Fig. 3.1. a-c)**.
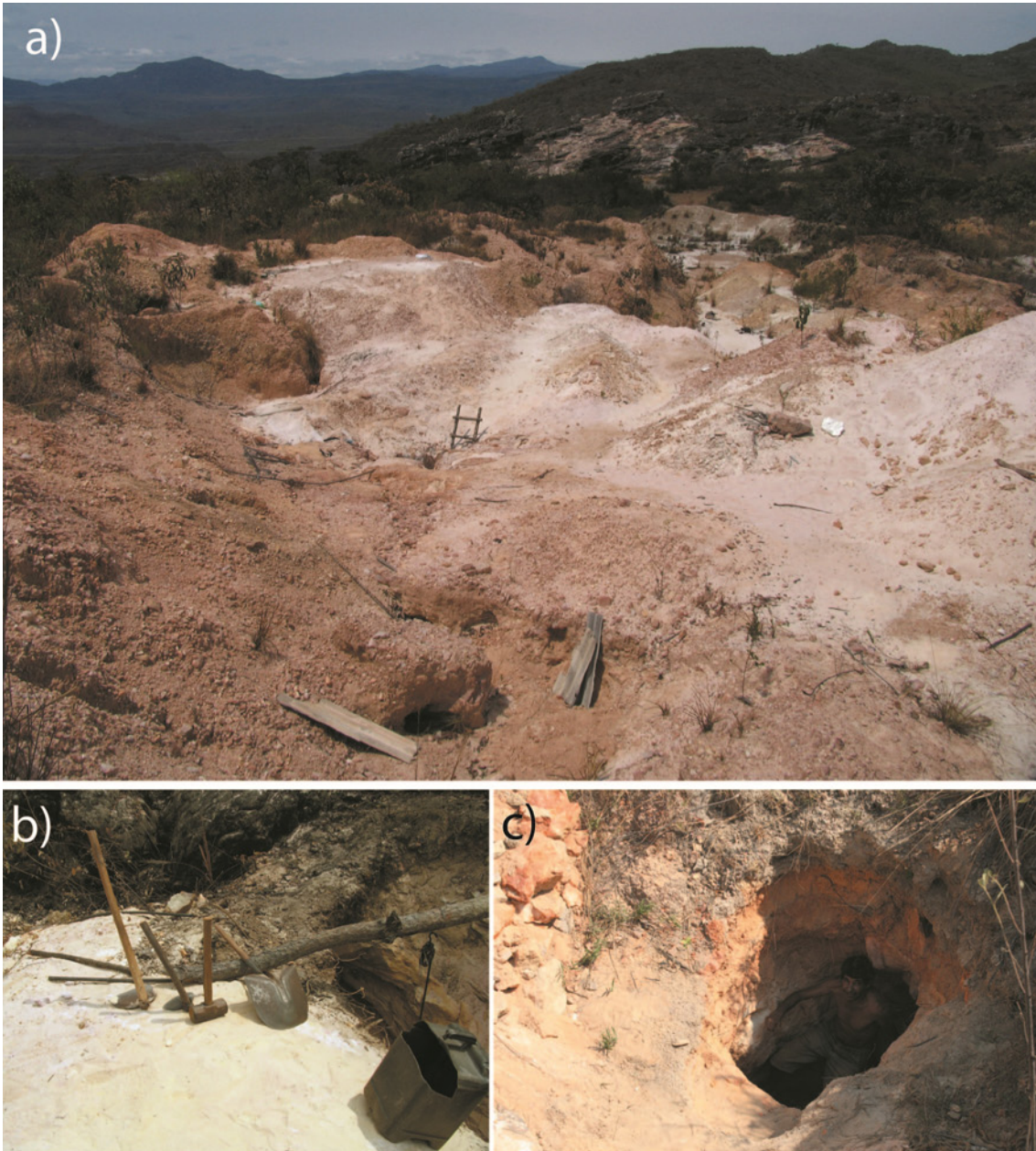
Fig. 3.1. a-c: Contemporary rock crystal mining at Cabaçaco, Minas Gerais, Brazil. a: Mining field; b: mining tools; c: *Garimpeiro* (=miner) Renato Nonato dos Santos in his shaft (*Photos: M. Brandl 2011*).

Roth (2008) undertook investigations concerning the history of economics at the Arnhofen mining site in Lower Bavaria, comparing available data from different Middle and Late Neolithic (4400–ca. 2800 BC) chert and flint mining sites throughout Central and Western Europe. He found similar patterns regarding mining organization at an area extending between Central Poland and the Paris Basin, allowing for some general assessments.

It seems that areas potentially suitable for mining were divided amongst small groups, probably representing kinship groups (which is highly hypothetic in my opinion). Such groups consisted of not more than 3–4 members, which can be deduced from the size of the shafts. The mining activities were carried out seasonally on a part time basis additional to the main activities that fall within the farming economy. Particular groups were in possession of use rights at certain areas, which were probably inherited over generations. Roth (2008) derives these assumptions from the spatial organisation of the mining area at Arnhofen. However, he found no indication for fully specialised miners, nor could he identify "industrial" elements for the mining organisation (Roth 2008, 911-932).

3.1.3. Economical systems: resource distribution

Exploring the gathering of raw material in Neolithic times is one endeavor, however, explaining raw material displacement over large distances is more byzantine. When compared to the Palaeolithic, there is one major aspect that has serious implications on Neolithic societies: The massive increase of population density and sedentarism. According to Ericson (1981, 155), population increase inevitably leads to intensified intergroup contacts, reflected in more complex exchange networks. At this juncture, some terminological issues need to be addressed.

A discussion of resource procurement and allocation has to include a consideration of exchange and reciprocity. Taking current theory into account it becomes quite clear that "trade" in a modern form did not exist in Neolithic times.

The first to address this issue in social theory was Marcel Mauss (1925). Drawing upon examples from around the world (e.g., Melanesian Kula, American Northwest Potlatch, etc.), Mauss explores how human relationships build through the exchange of objects. In preindustrial societies, groups – not individual people – have the obligation to receive and give objects to others.

In The Great Transformations (1944) the Austro-Hungarian born Karl Polanyi delineates four types of resource allocation:

- self-sufficient householding,
- reciprocity (e.g., gift exchange),
- redistribution, in which resources are collected to a center which allocates and distributes them, and
- market exchange, which is a fairly recent phenomenon.

In the context of Neolithic raw materials that were distributed over long distances, householding is not an option. Since strictly economy based market exchange is a modern phenomenon, only reciprocity and redistribution are left as possible models to explain the allocation of Neolithic raw materials.

3.1.3.1. Reciprocity

Marshall Sahlins (1974, 193), who extended and critiqued Polanyi's model, distinguishes between three levels of reciprocity. The first level, generalised reciprocity, describes the altruistic gift, a present given without expecting a gift in return. In an extenuated form, this term can also refer to the delayed exchange of gifts. The second level is the balanced reciprocity, referring to equivalent transfer of goods, closely related to inter-social relations. The third layer is defined as negative reciprocity. When applying this form of exchange, an imbalance occurs on one side of the transferring parties. This implies receiving more for a product than investing in the manufacturing process and/or the effort of obtaining it. As such, this is marked-based trade paralleling our contemporary market system and, in the most extreme form, theft.

The first two levels of reciprocity are usually linked to societies with flat hierarchic structures, whereas the third form – the negative reciprocity – is considered as typical for more complex sociopolitical systems (Roth 2008, 594). Based on all available data, Neolithic societies did not display a very strong hierarchic society model (Brandl 2009, 21-23; Roth 2008, 592).

Colin Renfrew further elaborated these models by graphically illustrating the link between geographical relationships and the aforementioned modes of exchange in characteristic fall-

off curves (Renfrew 1975). The first and superficially most simple form of passing on goods is represented by *"down the line exchange"* (Renfrew 1972, 465-469). Simplified, it describes the transfer of materials starting at the source from one settlement to the next. The agents (= the "exchangers") only move to their immediate exchange partners. Within such a system, small amounts of material can still occur at very distant sites, depending on the density of the involved exchange network. According to Roth (2008), the regularity rather than the abundance of the occurrence of exotic raw materials is an indicator for communication intensity between a source region and the final destination. Generalised and/or balanced reciprocity are traditionally understood to be linked to down the line exchange systems (Roth 2008, 920).

While *"down the line exchange"* is situated at the non-commercial end of the continuum, *"directional trade"* is located at the other end of the scope. According to Renfrew (1972, 471), *„useful commodities are now transferred from the source preferentially to special destinations, intermediate localities not preferentially favoured in this way, are less well supplied."* The supply of the target-groups is not necessarily directed by a central authority. However the economic untertakings clearly display an autonomous character (Roth 2008, 626).

3.1.3.2. Redistribution or redistributive exchange

Redistribution is typically associated with two main factors, the establishment of central places and central organization (Renfrew 1975, 8). According to Peoples & Bailey (2012, 145), redistribution is *"the collection of goods or money from a group, followed by a reallocation to the group by a central authority."*
The existence of central places is archaeologically evident, however their function must not be confused with market places. There are also indications for centralized organization to a certain degree, at least occasionally (e.g., in the course of construction projects that require a great number of laborers). Although there is no definitive proof for redistributive exchange at Neolithic societies in Middle Europe, it cannot be categorically excluded.

3.1.3.3. Current theories concerning the distribution of Neolithic raw materials

Since displacement of goods (in this case rocks) are the central issue of raw material provenance studies, current theories that build upon the established models of transmission in the Neolithic shall also be addressed very briefly.

Andreas Zimmermann (1995) draws a more or less clear connection between varying forms of reciprocity, partition of labour, location of settlements, economical archaeology and archaeological characteristics (Zimmermann 1995, 61-62). However, de Grooth (1994, 113) and Roth (2008, 589-634) critique the absoluteness of such far reaching considerations. Roth interprets varying distribution patterns of Arnhofen chert in sites of different chronological stages directly linked to differing exchange-systems (Roth 2008, 927).

Recently, David Graeber (2011) presented innovative ideas concerning the origin of economical systems. Most economists interpret the development of economy as derived from simple systems of exchange, based on mutual interest, with the subsequent application of money and dept. However, it is challenging to rethink this model and to look at it the other way around: As an economy based on social units with certain obligations and objectives constituting commitments that eventually lead to specific forms of exchange. As demonstrated in ethnographic studies, barter, for instance, was only observed between strangers or even enemies, but never applied between "fellow villagers" or neighbouring friends (Graeber 2011, 29-32).

3.1.3.4. Beyond economy

Since rare exotic raw materials representing outliers at sites situated at the external borders of exchange networks can be barely interpreted as parts of the regular supply system, different aspects have to be taken into consideration. In her study concerning distance and otherness, Helms (1988) noted that "distance" is an important cultural-historical parameter in premodern societies. Geographical (= horizontal) distance is associated with transcendental (= vertical) distance, which transfers people or goods from distant regions into "higher" spheres (see a more detailed discussion on that issue at Roth 2008, 632).

3.2. Flint and chert utilization in historical times

Post-Stone Age chert/flint exploitation and use never became entirely extinct, but experienced its renaissance in the course of military engagement in the form of gunflint production. Gunflints were distributed all over the world by the millions beginning with the introduction of the flintlock rifle in the 17th century as an important part of military equipment. Main production areas for gunflints were situated in France, England, Spain, Italy, and Poland (see Chapter 5.3.).

However, there is a widely unconsidered social-historical component to gunflint production. Poverty, occasionally interrupted by devastating famines, was prevailing in 18th and early 19th century Europe. Gunflint manufacturing communities were able to establish a secure source of revenue due to the persistent need of gunflints, especially during the Napoleonic Wars.

Witthoft (1966, 40) examined the impact of gunflint production on various spheres of life. Concerning social aspects he comments: *"(gunflints) are part of a social history of European technology. The men who made them gained some slight prosperity. Gunflint towns were among those craft-centres that rose like islands slightly above the sea of European poverty."* Communities participating in the gunflint business were part of early industrialization processes, e.g., through the employment of partition of labour, however the business was a very conservative one, taking into account that the technique of gunflint manufacturing remained practically unchanged for almost two centuries.

The "mystery" of how to mine proper flint for gunflint manufacturing and – even more important – the secret of gunflint production as such secured the life standard of those communities. It is therefore no surprise, that industrial espionage was a constant threat on the side of the producers and a challenge for those trying to establish own industries. Some historical sources report of enterprises by order of European sovereigns seeking to disclose the secret. In detail, this issue will be discussed in Chapter *5.3. Gunflints from Schloss Neugebäude.*

4. Analytical techinques

Quantitative methods have been applied in the past, although a clear differentiation of chert raw materials has yet to be achieved (Roll et al. 2005; Speakman & Neff 2005; Morgenstein 2006; Rafferty et al. 2007; Hughes 2010; Parish 2009; Cheben & Cheben 2010). Due to the numerous constraints and limitations inherent in every analytical method, a concept including several layers of investigation promises the most reliable results. For this thesis, a multi-layered approach was applied, combining visual (macroscopic), microscopic, mineralogical and geochemical aspects. This methodological system will be referred to as MLA from this point forward, with the particular steps as MLAS 1–3.

Geological formations do not display highly standardized patterns. They are comparable, however, they are not uniform. This is why all analytical levels of the MLA adhere to the mnemotechnic principle:

Standardize when possible and individualize when necessary.

4.1. Analytical steps of the MLA

MLAS 1: Macroscopical (visual) investigation
The first and indispensable step in lithic raw material analysis is a precise description of macroscopically characteristic properties. The investigation of such features allows an initial classification of lithic raw materials. Colour, knapping features and texture are basic attributes to be investigated. Colour descriptions are based on the Munsell geological rock-color chart (GSA 2009), the measurement of granularity follows **Table 4.1.**

name		size range
Very coarse soil	Large boulder, LBo	>630 mm
	Boulder, Bo	>200–630 mm
	Cobble, Co	>63–200 mm
Coarse soil	Gravel	Coarse gravel, CGr	>20–63 mm
	Medium gravel, MGr	>6.3–20 mm
	Fine gravel, FGr	>2.0–6.3 mm
	Sand	Coarse sand, CSa	>0.63–2.0 mm
	Medium sand, MSa	>0.2–0.63 mm
	Fine sand, FSa	>0.063–0.2 mm
Fine soil	Silt	Coarse silt, CSi	>0.02–0.063 mm
	Medium silt, MSi	>0.0063–0.02 mm
	Fine silt, FSi	>0.002–0.0063 mm
	Clay, Cl	≤0.002 mm

Table 4.1.: Granularity of sediments and rocks

Source: BSI 2009. Table adapted from pg. 7, table 1a.

The translucidity of raw material samples is described according to a three-grade system:

Translucent: A specimen in front of a light source allows the light to permeate without major darkening effect.

Semi-translucent: The light pierces through the specimen, but is partly blocked by inclusions and/or the rock structure.

Non translucent: Light is not able to pass through the specimen.

Certain type varieties can be defined within archaeological assemblages and in geological deposits. It is well known that every geological source contains several type varieties, and in many cases these varieties show a higher difference within the same source than between distant sources. This effect makes a purely macroscopical assignment of archaeological material even more difficult (Ludtke 1992, 71-72; Elekes et al. 2000, 503; Mateiciucová 2008, 44-56, *possible confusions*; Bustillo et al. 2008, 20-21). However, natural scientific undertakings have addressed this issue in order to verify the accuracy of visual assignments (Elekes et al. 2000, 504; Biró et al. 2009, 25).

MLAS 2: Microscopical investigation

The second level of investigation – microscopical analysis – provides detailed information concerning inclusion, especially fossils, in chert. The goal of these investigations is the classification of characteristic fauna communities in specific sources in order to identify or narrow down raw material clusters (Brooks 1989). For comparison, micropictures were produced using a reflected light stereo microscope (standardized 20x magnification). All pictures were taken from unpolished surfaces. The pictures were taken from representative specimens, not necessarily of such sampled for geochemical analysis, because they are in most cases not suitable for microscopic photography, lacking large straight surface areas.

MLAS 3:

Petrographical-mineralogical analysis

In some cases, mineralogical investigations were conducted additional to geochemical analysis at the Department of Geosciences at the Universalmuseum Joanneum at Graz. The mineral content was determined applying X-ray diffractometry (XRD), a technique for analyzing a wide range of crystalline materials. This method allows for the detection of crystalline mineral components in small amounts. The detection limit highly depends on the analysed minerals, typically ranging between 2-3 vol.%. A Bruker AXS D8 diffractometer was used for long-term recordings of the radiolarite samples (CuKα-radiation, Si-carrier, 5-70° 2-Theta, Step: 0.02°, Step time: 836.1 s). The objectiv was (1) the identification of minerals included in the samples (feldspar, clay minerals, etc.) and (2) the proof of moganite as described by Pristacz (2008) and Bechter et al. (2010). For the purpose of comparison, sample material was taken from the same area of the rocks as the samples for geochemical analysis.

Secondary electron images displaying the surface of the samples were obtained by a JEOL JSM 6310 scanning electron microscope (SEM) at the Institute for Earth Sciences, University Graz. The electrons interact with the atoms of the sample producing signals that contain information about the surface topography, material composition and further properties of the sample.

Geochemical analysis

For geochemical analysis, Laser Ablation-Inductively Coupled-Mass Spectrometry (LA-ICP-MS) was applied. This method allows a spacially resolved detection of trace elements with a detection limit of approximately 0.1 ppm[2], data below 1 ppm illustrate a higher analysis error and need to be treated with caution.

A pulsed laserbeam hits the surface of the sample ablating small particles. This ablated material is transported to the ICP-MS unit via helium gas-stream. The material is ionized in the argon plasma, and eventually the range of elements is detected in the mass spectrometer. The reference glasses NIST610 and/or NIST612 are used as standards. Silicon (m/z 29) was used for internal standard correction.

Representative single grains of sample material, measuring 2x2 mm in average, were embedded into a resin mount and polished for Laser ICP-MS analysis. On each sample 3–5 analysis spots are measured, the mean is graphically plotted.

As a rule, inclusions naturally occurring in chert materials and influencing the measured result minimally were not substracted from the raw data, since they represent the natural consistency of the raw material. Only in cases substantially changing the results (e.g., clearly definable mineral inclusions as outliers), these data points were adjusted by levelling the anomalous peaks. All geochemical results are provided in **Appendix D5 (Geochemical results)**.

Case study I: Tabular chert (Rein vs. Baiersdorf)

Laboratory: University of Graz, Institute of Chemistry-Analytical Chemistry.

LA-ICP-MS unit: New Wave UP-213 (Fremont, CA, USA); ICPMS unit: Agilent 7500ce ICPMS (Waldbronn, Germany).

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[2] 1 ppm corresponds to 0,1 wt.% = 1000 g/t in rock material.

Measurement conditions:

Material was ablated by using a 213 nm laser pulsed at 5 Hz, 40 μm spot size and 80 % laser power which corresponds to an energy of ~7 J/cm2. Helium 5.0 at 1.0 l/min flow was used as carrier gas for the Laser ablation and data was acquired in time resolved analysis mode.

Standards: The standard glass NIST610 was routinely analyzed for standardization and drift correction.

Unknowns: The standard glasses NIST612 and BCR-2 were analyzed as unknowns and allowing for their reproduction within 10 % relative error **(Appendix D6, Table Standard deviation)**.

Case study II: Radiolarites

Laboratory: Central Lab for Water, Minerals and Rocks, NAWI Graz, University of Graz and Graz University of Technology.

LA-ICP-MS unit: ESI NWR-193; ICPMS unit: Agilent 7500.

Measurement conditions:

Material was ablated by using a 193 nm laser pulsed at 5-10 Hz with 40-80 μm spot size and a laser power which corresponds to the energy of ~7 J/cm^2. Helium 5.0 at ca. 0.8 l/min flow was used as carrier gas for the aerosol produced by the laser ablation, data was acquired in time resolved analysis mode.

Standards: The standard glasses NIST610 and/or NIST612 were routinely analyzed for standardization and drift correction.

Unknowns: Standard glasses NIST612, NIST614 and BCR-2G were analyzed as unknowns and allowed for their reproduction within 10 % relative error **(Appendix D6, Table Standard deviation)**.

Case study III: Schloss Neugebäude gunflint cache

Laboratory: Central Lab for Water, Minerals and Rocks, NAWI Graz, University of Graz and Graz University of Technology.

LA-ICP-MS unit: ESI NWR-193; ICPMS unit: Agilent 7500.

Measurement conditions:

Material was ablated by using a 193 nm laser pulsed at 5-10 Hz with 40-80 µm spot size and a laser power which corresponds to the energy of ~7 J/cm^2. Helium 5.0 at ca. 0.8 l/min flow was used as carrier gas for the aerosol produced by the laser ablation, data was acquired in time resolved analysis mode.

Standards: The standard glasses NIST610 and/or NIST612 were routinely analyzed for standardization and drift correction.

In the case of Ge, NIST 612 (Jochum et al. 2011) was used as the standard

Unknowns: The standard glass NIST 614 reproduces within 5% error **(Appendix D6, Table Standard deviation)**. NIST 614 is suitable to evaluate the analytical accuracy because it has a SiO2 rich matrix (~71 wt.%) which is close to chert and flint, and shows trace element concentrations around 1 ppm.

4.2. Statistical evaluation of the geochemical data

Element concentrations were calculated from raw data with Glitter data reduction software (v. 4.41, Macquarie, Australia) and graphically plotted using a GeoChemical Data toolkit (GCDkit v. 2.3). Written in R, it allows for data handling acquired from geochemical analysis. It is designed for standard geochemical calculations including REE and trace elements with the option of displaying x–y-ratio plots of the concentrations detected in rock materials.

In the course of the publication of the radiolarite study, compositional data analysis (CODA) was applied and produced compelling results. In the future, this concept will be heavily incorporated into the evaluation of geochemical data, however for the present study I decided to rely on the conventional system (x– y-trace element concentration plots).

5. Case studies

The three case studies are intended to demonstrate the practical application of the MLA in different geological and archaeological environments. Parts of the Rein versus Baiersdorf tabular chert study were published in the course of the revision of the Repolust Cave find material in 2011 (Brandl et al. 2011), the radiolarite investigations are part of a publication project concerning the Upper Palaeolithic Krems-Wachtberg site (Brandl et al. 2013). The gunflint study was conducted in order to test the MLA within a broader range – geographically and archaeologically.

5.1. Rein vs. Baiersdorf

5.1.1. Introduction

Prehistoric chert stone tools regularly occur at both, Palaeolithic and Neolithic sites in present day Styria. In the course of the investigation of those assemblages, a whitish-grey non-translucent tabular chert with a sandy-yellow cortex was recognized as diagnostic raw material and subsequently defined as "index fossil" of Styrian lithic find complexes (Sigmund 1924; Moser 1989; Obereder 1989; Einwögerer 1999). Until recently, the only known deposit producing a visually similar raw material is the Baiersdorf chert source located at the Franconian Alb, in the Bavarian Kelheim district (Binsteiner 1989). It is therefore not surprising that archaeologists working on Styrian chert finds assigned the origin of that tabular chert variety to the latter source region. An additional argument was the proofable wide distribution of Baiersdorf chert during the Late Neolithic (mainly of the Altheim group, 3800-3400/3300 BC).

It was not before the connection between a tabular chert deposit in the Rein Basin near Graz (Styria), which was only described in mineralogical literature, and the archaeological finds (Brandl 2009, 43-47), that the origin of Styrian tabular chert artifacts from the Baiersdorf source was called into question.

Since the raw materials from the Rein and Baiersdorf chert sources are visually very similar, macroscopical investigations are not sufficient for source distinction. Considering that the two sources were formed under different geological parameters, a pilot study applying mineralogical, petrographical and geochemical analyses using LA-ICP-MS appeared

promising. Eventually, the results were applied to a representative number of chert artifacts from the most important Neolithic sites in Styria and the Palaeolithic assemblage from the Repolust Cave. In actuality, this case study was the first to test the applicability of the MLA proposed in this thesis.

5.1.2. The Rein Basin chert deposit: Research History

Peters (1853) and Hatle (1885) were the first to give account of chert finds in the Rein Basin, describing a series of chert bearing clays and limestones exposed in the course of coal mining activities in the region around Enzenbach and Hörgas. These early literary sources mention the presence of chert, however they do not consider the archaeological value of their observations and were therefore neglected by archaeological research. Nearly 100 years later, Alker (1979) reports on chert occurrences in the Rein Basin. Again, this publication remained unnoticed by archaeologists. Alker conducted analysis on both, nodular and tabular chert varieties from the Rein Basin chert deposit. Even though two chert artifacts originating from the Repolust Cave are kept together with raw material samples from Rein in the collection of the Universalmuseum Joanneum, Alker seems to have lost interest in further investigating this issue. In the 1980s, the speleologist H. Kusch assumed a prehistoric use of the Rein Basin chert, because he recognized similar material to that published by Alker in several Styrian cave sites (Postl et al. 2008b, 118). However, his assessment could not be verified at that time.

In the course of a systematic review of Neolithic chert finds from Styria, Einwögerer (1999, 206) excludes the possibility that tabular cherts originate from the Rein Basin and, following the interpretation of his German colleges, considers their provenance predominantly Southern Bavaria.

In 2004, the private collectors J. Jakely and H. Könighofer made contact with the mineralogist W. Postl from the Universalmuseum Joanneum and asked him to investigate repeated chert finds from the Ulrichsberg located in the western part of the Rein Basin (west of the monastery). In the same year, M. Brandl and H. Hiden commenced geological surveys at agricultural fields on the plains of the Rein Basin and on the slope of a slight hill to the north of the fields, where great numbers of tabular chert were exposed by agricultural activities. Eventually, all researchers merged into a team with the goal to investigate the Rein Basin

chert source. In 2007, the mineralogist and petrologist C. Hauzenberger joined the team and offered the possibility of conducting geochemical research using the LA-ICP-MS unit at the Karl-Franzens University in Graz. Simultaneously, thorough natural scientific investigations of the Rein Basin chert were initiated. Preliminary results were published as geoscientific paper (Postl et al. 2008a), in a consolidated article by the team (Postl et al. 2008b) and subsequently in the course of the release of the master's thesis by Brandl (2009).

Mineralogical, petrographical and geochemical analyses conducted by Postl and Hauzenberger primarily aimed at the differentiation between the visually similar chert varieties of the Rein and Baiersdorf chert sources. Eventually, the results should be applicable to archaeological finds. This was achieved in 2010, in the course of the revision of the Repolust Cave assemblage (Brandl et al. 2011). Concurrently, numerous Neolithic find complexes from Styrian sites were included into the investigations.

The uppermost areas of the Rein Basin chert deposit could be examined in the course of the earthworks for the construction of a swimming pond in 2008 at the foot of the hill surveyed by Hiden and Brandl four years earlier.[3] The geological profile revealed layers of low-quality tabular chert (see a more detailed description below). This reinforced the idea that prehistorically used raw material of much higher quality (as observed by Hiden and Brandl in 2004) only occurred at a locally restricted area within the Rein chert deposit.

Excavation at the Rein chert source 2010

In order to clarify the geological setting, M. Brandl and D. Modl conducted a small excavation on the slight slope at Rein-Hörgas surveyed in 2004 and suspected to deliver high quality chert. Additional advice from the owner of the property and local people knowledgeable of the environment assisted us in determining the locale of the excavation.[4]

A 1x2 m trench was placed at a position supposed to be sterile. On the surface, no indication of archaeological features was present. After removing ca. 15-20 cm of aggradation material dating to the late 1960s, the outlines of two objects were encountered. These were the uppermost remains of quarrying pits **(Fig. 5.1.1. a and b)**. The pits are filled with

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[3] We owe many thanks to Dr. Zurl, Hörgas 298, for the possibility of conducting the examination.
[4] Many thanks to G. Rottenmanner and A. Feichtenhofer.

intermingled sediments of the Rein Layers, visibly isolated from the surrounding bedrock at a depth of ca. 100 cm below the top soil.

Spatial constraints did not allow for the full excavation of the pits. On that account, the full extent of the pits is not known. The larger of the two pits, defined as "quarrying pit 2", almost covered the entire excavation **(Fig. 5.1.2.)**, whilst "quarrying pit 1" was only cut at the corner of the trench and soon ended at the profile **(Fig. 5.1.3.)**. After the removal of the archaeological material the interfaces of the pits revealed defined entrance areas. Apparently, steps were created by the prehistoric miners in order to access the quarrying pits. The profile shows pit 2 steeply dipping in at the south-eastern part and that it was dug in leaving a half landing in the south-western part. The same pertains to quarrying pit 1 **(Fig. 5.1.1.)**.

Fig. 5.1.1.: Quarrying pits 1 and 2, 2010 excavation campaign

a: Photo *(M.Brandl).*
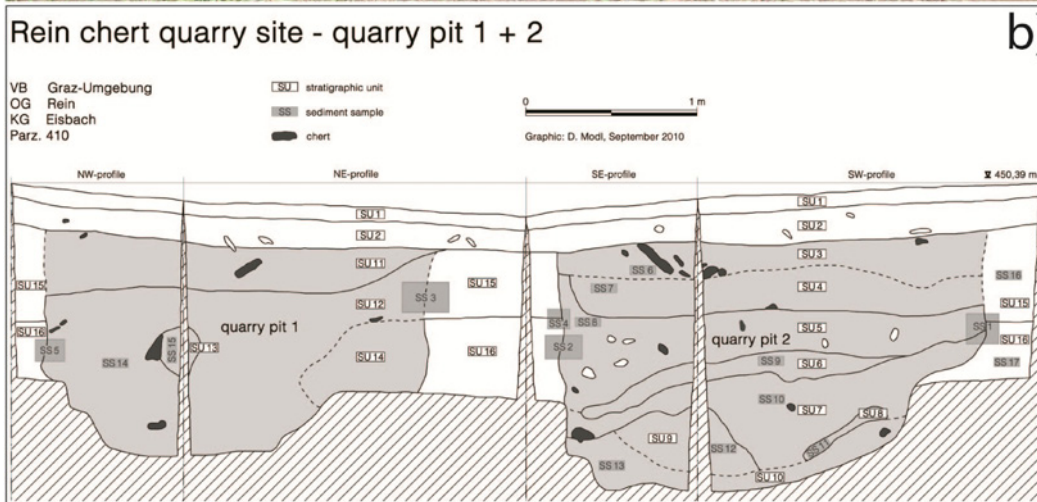
b: Drawing of the profile *(D. Modl).*

Fig. 5.1.2.: South profile (pit 2)   **Fig. 5.1.3.: North profile (pit 1)**

Photos: M. Brandl.

The lithics recovered from the quarrying pits show the complete chaîne opératoire of a flake-producing chert knapping industry **(Fig. 5.1.4.** and **Table 5.1.1.)**, roughly rectangular pre-shaped chert plates (e.g., **Fig. 5.1.4., no. 6**), exhausted cores (e.g., **Fig. 5.1.4., no. 4**), tested pieces, flakes and few modified tools. Additionally, a nodular chert variety unknown from the Rein chert source (type Rein 8) was discovered (see detailed description below).
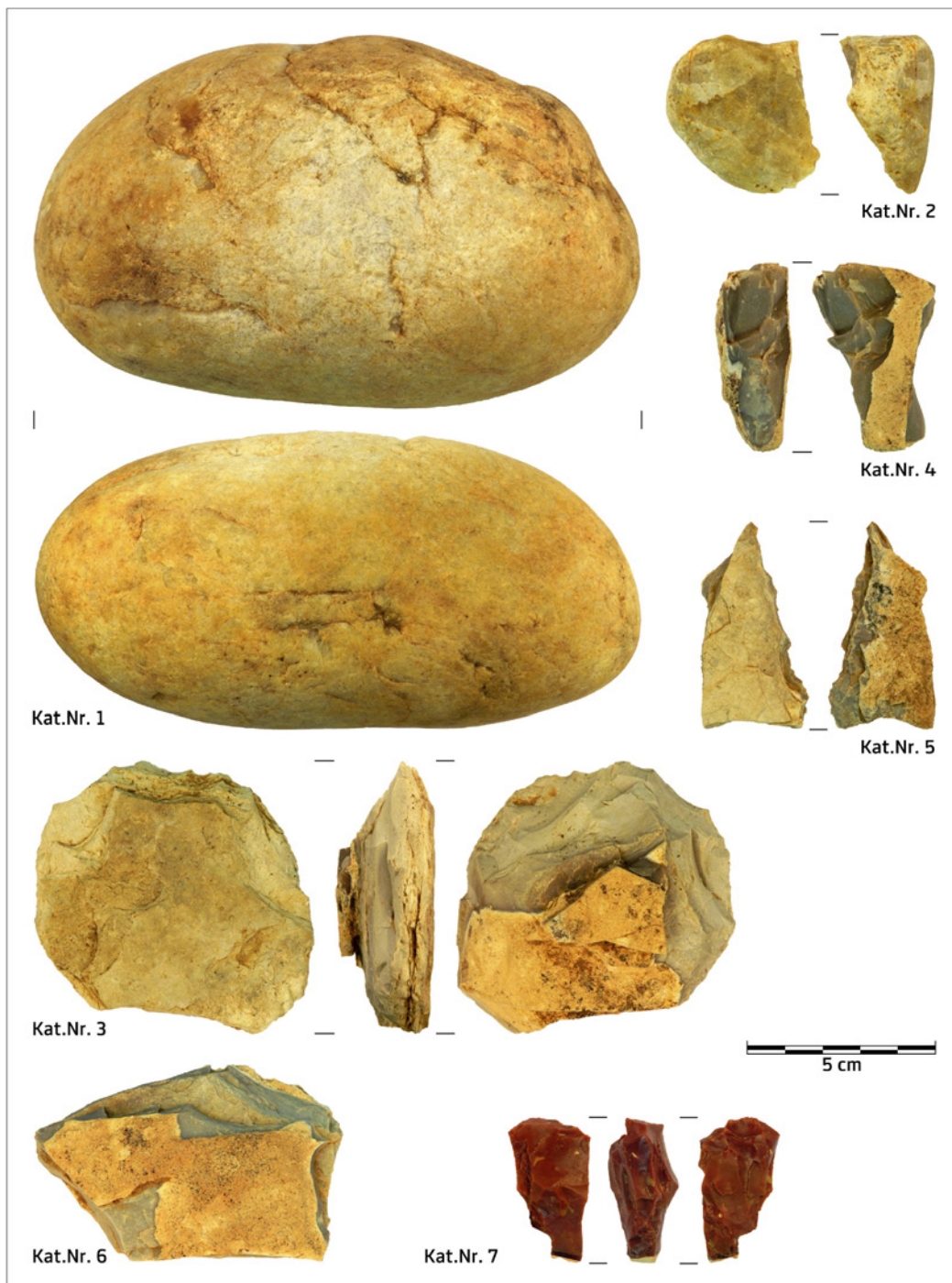
Fig. 5.1.4.: Selected finds from the 2010 excavation at Rein

Photo: D. Modl.

No.	description	raw material	raw material type/ provenance
1	**anvil stone** (knapping device)	quartz	local river gravel
2	**hammerstone fragment**	quartz	local river gravel
3	rescharpened **mining tool**, secondary use as **hammerstone**	tabular chert	Rein III[5]
4	**exhausted core**	tabular chert	Rein IV
5	unfinished/ rejected **sickle blade** (Altheim type).	tabular chert	Rein III
6	tested and roughly **rectangular shaped chert plate ("bar")**; rejected due to poor quality	tabular chert	Rein III
7	**exhausted core**	radiolarite	Szentgál Tüzköveshegy type

Table 5.1.1.: Description of the selected lithic finds from Fig. 5.1.4.

Graph: M. Brandl.

A total of 8 charcoal samples were collected from quarrying pit 2, of which 4 were suitable for radiocarbon dating. Microscopical analysis of the samples was conducted by O. Cichocki (Institute for Palaeontology, University Vienna) for the determination of the wood species present at the site **(Table 5.1.2.)**. C-14 data **(Table 5.1.3.)** show a relatively narrow time span of the filling of the pits, indicating mining activities taking place during the middle stage of Lasinja (ca. 4400-3700 BC according to Samonig 2003, 41). The excavation established the first proof of Neolithic quarrying activity at the Rein Basin.

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[5] Descriptions of the Rein chert number system are provided below.

sample no.	determination O. Cichocki 2011	C14
HK 1	Coniferous wood without resin canals, fir or yew tree; fir is more likely	x
HK 2	Coniferous wood without resin canals, fir or yew tree; fir is more likely	
HK 3	Microporous deciduous wood, hornbeam? Uncertain	x
HK 4	Part of a root or base of a brench, no further determination possible	
HK 5	*Rosaceae*	
HK 6	Porous oak tree	x
HK 7	Porous oak tree (narrower tree rings than those from HK6)	x
HK 8	Coniferous wood, indet. (sample is too small and poorly preserved)	

Table 5.1.2.: Charcoal samples from the Rein quarrying site

Graph: M. Brandl.

Lab-No.	Sample	$\delta^{13}C^{1,2)}$ [‰]	^{14}C-age[1] [BP]	Cal. Age[3]
VERA-5633	HK1 Eisbach	-27.8 ± 0.9	4955 ± 35	3800BC (95.4%) 3650BC
VERA-5634	HK3 Eisbach	-33.4 ± 1.0	5600 ± 35	4500BC (95.4%) 4350BC
VERA-5635	HK6 Eisbach	-31.0 ± 0.9	5340 ± 35	4320BC (4.6%) 4290BC 4270BC (90.8%) 4040BC
VERA-5636	HK7 Eisbach	-30.7 ± 1.5	5395 ±35	4340BC (80.7%) 4220BC 4210BC (9.6%) 4160BC 4130BC (1.7%) 4110BC 4100BC (3.4%) 4070BC

[1] 1σ –error.

[2] The $\delta^{13}C$-values were detected by AMS-system.

[3] Calibrated applying the OxCal-program, values show a 2σ-confidence interval, probability for the respective timeframe in brackets.

Table 5.1.3.: Radiocarbon data of charcoal samples from the Rein quarrying site.
The data were acquired at the VERA-Laboratory,
Department of Isotope Research and Nuclear Physics, Vienna.

In 2011, the so-far last investigation for a better understanding of the complex setting of the Rein Basin chert deposit was carried out when Brandl and Modl rediscovered the well-shaft described by Alker (1979), from which the only few raw material samples of nodular chert derived. According to the owners of the property, the well was dug out in 1964 and the depth was increased in 1975. During the latter undertaking, the chert bearing layer was encountered at an approximate depth of 8m.[6]

5.1.3. Baiersdorf versus Rein – an analytical challenge

The present case study was the first to be conducted testing the MLA, greater analytical effort was invested to examine the applicability of several methods (e.g., IR-spectroscopy). In order to comprehend the underpinnings of this research, a brief characterization of the raw material deposits of Rein and Baiersdorf is discussed below.
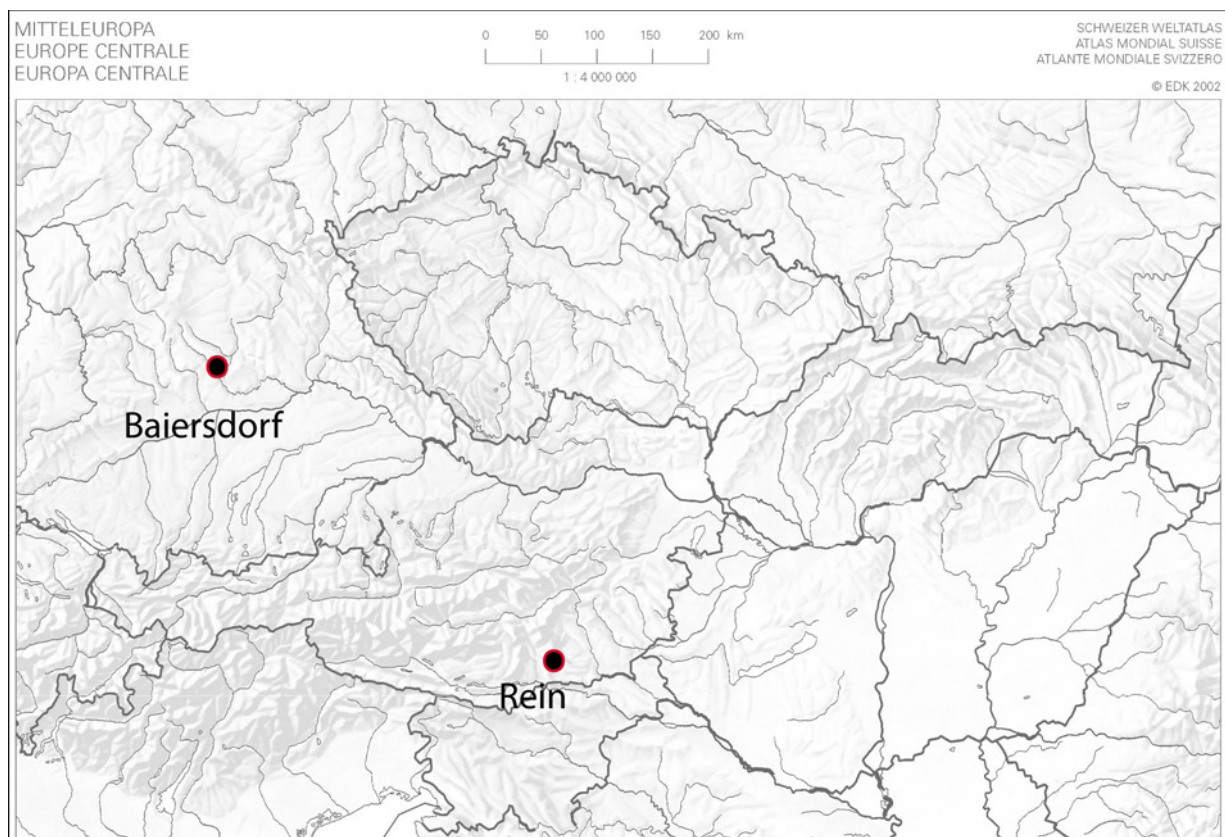
Fig. 5.1.5.: Location of the Rein and Baiersdorf chert deposits

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[6] We thank Thomas Peiser for the kind information.

5.1.3.1. Rein

Geographical setting

The chert occurrence of Rein is located in the so-called Rein Basin, which is located ca. 12 km northwest of the Styrian capital of Graz, west of the Mur river **(Fig. 5.1.5.)**. The Rein Basin is surrounded by rolling hills which make the area a perfectly enclosed settlement chamber. It is accessible from the south through the narrow valley between the Kalvarienberg and the Schneiderhöhlenkogel, confined by the hill range of Hörgas in the northwest. Situated in the western part of the Rein Basin, the Ulrichsberg rises to an elevation of 520 m a.s.l., with the Cistercians monastery at the foothills. The chert source is situated on a shallow ridge sloping north-south towards the bottom of the basin. The mining area presumptively covers three hectars on the lower southern part of the slope.

Geological setting

The Rein Basin is part of the Styrian Neogene Basin, the chert deposit is bound to the so-called "Rein Layers" (Schichten von Rein). According to Ebner & Gräf (1979, 11-15), the geological profile of the basin shows the following constitution:

Paleozoic limestones, dolomites, sandstones and schists form the basis of the Rein deposit. Above of the bedrock lies a sequence of the Badenian, consisting of Eggenberg breccia, red earth (Laterites) and a formation referred to as "Reiner Schichten" (Rein Layers). These form a subunit of the Stallhofen Formation which covers large areas within the Western Styrian Neogene Basin. Both the Rein Layers and the Stallhofen Formation date back to the Badenian, the main difference lies in the occurance of limestone banks within the Rein layers. They are composed of freshwater marls and -limestones, blueish and light clays, sands, freshwater breccia and sporadic intercalated coal seams. Locally limited, tuff- and bentonite horizons are imbedded in those layers. Sandy-gravely, fluvial sediments known as "Eckwirtschotter" (Eckwirt gravels) and, locally restricted, loamy components of Pleistocene age overlay the Rein Layers (Ebner & Gräf 1979, 11-15; Flügel 1984, 23).

Linked to the Rein Layers, two varieties of microcrystalline SiO_2 were formed, tabular and nodular cherts. According to Alker (1979, 8) and Ebner & Gräf (1979, 15), the nodular chert variety originates from deeper parts of the Rein layers (bentonite-level I), whilst the tabular variety occurs within the stratigraphically higher zones unattached to the Bentonite.

As indicated above, the geological profile of the upper parts of the chert deposit was documented in 2008 when a swimming pond was constructed at Rein Hörgas **(Fig. 5.1.6.)**.

Fig. 5.1.6.: South-west profile of the exposure at Rein Hörgas 2008

Photo: M. Brandl.

Apparently, the chert layers are bound to red earth strata (laterites). At the basis of those laterite layers, representing weathering horizons of freshwater limestone banks, continuous layers of chert preserved as hard rock components. They show a faulting 90° to the gradient, indicating Pleistocene permafrost conditions.

Two laterite horizons could be distinguished, an upper layer bearing white and coarse grained tabular chert up to 7 cm thickness at ca. 120 cm below the top soil, and a lower stratum at 190 cm depth containing blueish-grey homogeneous chert with a thickness up to 2 cm thickness. Some chert plates from the lower stratum show a double sequence separated by a thin chalk

layer. Nodular chert was not present at the exposure.

In detail, the south-east profile shows the following setting (bottom-up):

0 cm	lacustrine chalk sequences
70 cm	blueish-grey loam
110 cm	underlaying red earth (laterite) stratum with chert plates up to 2 cm thickness (occasionally double-layered)
120 cm	white chert
150 cm to	blueish-grey loam, sterile
180 cm	red earth containing white tabular chert, 6-7 cm in thickness, at the basis of the red earth layer
from 180cm to top soil	disturbed area

A total depth of 300 to 320 cm below the top soil was reached and documented during the campaign (documented with assistance from H. Hiden).

In his master's thesis, the author defined four varieties of the tabular chert from Rein (Rein I-IV). An additional fifth variety (Rein V) was recognized and described separately. In the course of investigations on the lithics from the Repolust Cave, predominantly nodular chert was detected. An origin from the Rein Basin was hypothesized for those chert finds, and two main types prevalent in the assemblage were defined as Rein 6 and Rein 7. A differentiation between tabular and nodular chert in the definition system was achieved by naming the first in Roman numbers and the latter in Arabian numbers. In the course of the excavation of the Neolithic quarrying site by Brandl and Modl in 2010, a nodular chert type differentiable from those present at the Repolust Cave was discovered and eventually defined as Rein 8. Subsequently, all established chert varieties from the Rein Basin are described in detail.

Chert varieties from the Rein Basin – macroscopical description (MLAS 1)

Nodular chert: Varieties Rein 6 and 7

In the course of the construction of a well shaft in Rein, in the district of Hart, nodular chert was discovered in the late 1970s. This particular chert variety shows a concentric layered structure with a nearly black core part. The coloration of the outer layers ranges from increasingly brighter tones of brown to almost white at the natural surface **(Fig. 5.1.7.)**. These visually distinct layers were mineralogically investigated by Alker (1979, 1-5) and in the course of the present case study.

From core to cortex, the following constitution of the chert nodules was detected: Quartz → quartz + tridymite → quartz + tridymite + dolomite → dolomite. Eventually, a transitional zone between the outermost dolomite layer and the surrounding limestone is present in most cases. The dark colour in the centre part of the nodules is ascribed to the presence of bitumen. The nodular chert occurrence of the Rein Basin is directly connected to the bentonite-level I described by Ebner & Gräf (1979, 12, Fig. 1).

Alker (1979, 5) describes the genetic processes of this chert variety as follows:

1. Volcanic ashes were converted into bentonite in the course of post-depositional processes, and SiO_2 was released.

2. Subsequently, SiO_2 (Opal, Tridymit, Quarz) solubilized and eventually precipitated.

3. Calcite was replaced by SiO_2-minerals, respectively by dolomite.

Based on the few comparable samples from the Rein-Hörgas well shaft, the thickness of the chert nodules is in a range between 25 and 35 cm. They show an irregular-roundish shape. Raw material variety Rein 6 has a semi-translucent brownish rock matrix, whereas Rein 7 is characterized by an entirely non-translucent grey coloration. Recent investigations revealed that both, Rein 6 and 7, can occur at the same nodule, which indicates fluid boundaries between those type varieties. Most likely, Rein 6 and 7 only represent different colouring effects at samples and can actually be equalized.
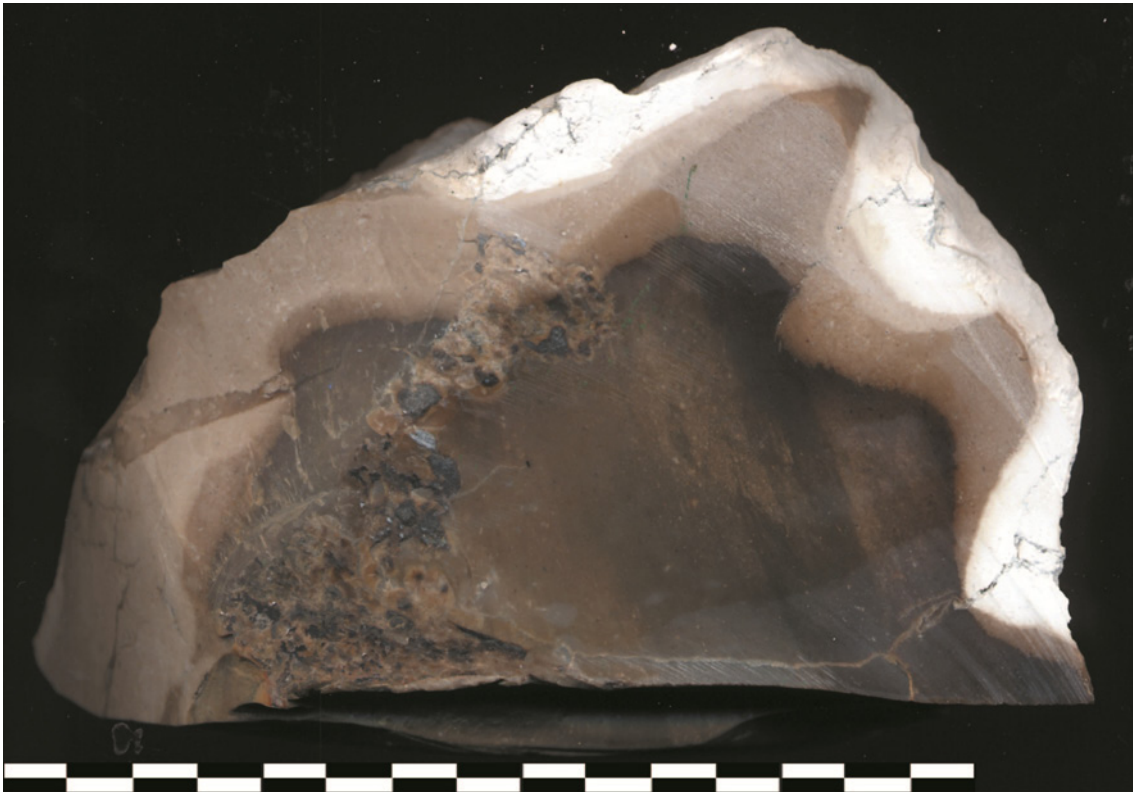
Fig. 5.1.7.: Nodular chert of the Rein 6/7 type variety from the Rein Basin

Photo: W. Postl.

Nodular chert: Variety Rein 8

In the course of the examining excavation of the Rein chert deposit in 2010, a total of 35 nodules of an unknown chert type were recovered and eventually defined as Rein 8 type variety. They range between 15 and 5 cm in diameter, most of them do nor exceed a size of 10 cm though **(Fig. 5.1.8.)**. Some specimens entirely consist of non-silicified lacustrine chalk. It is very likely, that chert of the Rein 8 type was formed in the course of the silification of such chalk nodules.

Rein 8 chert shows a light grey core region, changing into an intense white coloration towards the cortex. Specimens with patinated surfaces display a spotted appearance, caused by irregularly delimited areas of homogenous material interspersed into the silicified rock matrix. The cortex of Rein 8 chert corresponds to the natural surface at the tabular chert varieties from Rein, showing a sandy-yellow colour. In many cases, the cortex deeply extends into the nodules, with severely negative effects on the knapping properties. Additionally, the material is in most cases heavily cleft. At a fresh cleavage, the chert resembles porcelain, it breaks irregularly and into small pieces. Only 14 of 35 samples from the excavation show traces of

intential knapping, and all have been discarded due to the low quality after they were tested. None of the tested pieces was used for actual stone tool production, as indicated by the absence of nuclei showing traces of the characteristic core reduction processes. Apparently, nodules of the Rein 8 type were never the goal of Neolithic quarrying at the Rein Basin, but at best by-products barely ever present at sites out of the Rein source area. Investigations in the course of the master's thesis by Brandl (2009, 86-89) did not produce any evidence of Rein 8 chert in the most important Neolithic Styrian sites. All artifacts were produced from tabular chert varieties Rein I – V.

Fig. 5.1.8.: Nodular chert of the Rein 8 type variety

from the excavation by Brandl & Modl 2010

Photo: M. Brandl.

Tabular chert: Varieties Rein I–V

Additional to the above characterized nodular cherts, Alker (1979, 8) describes a variety of tabularly developed chert. This variety was observed by F. Ebner in the course of geological mapping activities at the former trash pit (midden) of the Rein village. According to Alkers investigations, the tabular chert type is purely constituted of quartz, and the natural surfaces of the analysed samples show cupuliform "solution pits". In contrast to the chert from the well shaft at Hart, the tabular chert layers are linked to segments of the Rein Layers not associated with the bentonite.

The genesis of the tabular chert is closely related to the lacustrine limestones in the upper areas of the Rein Layers. Chert occurs within the entire Rein basin up to an elevation of 440 m. Mineralogically, the chert from Rein is silicified freshwater limestone (Alker 1979). Alker refers the silicium to former glassy tuffs transformed into Bentonite. Hence, the source of the silica is related to the 14-17 Ma old Styrian volcanism (e.g., Gleichenberger Kogel).

The plate thickness of the Rein chert samples ranged between 7 and 22 mm. The colour variation showed whitish-brown to beige-grey, rarely blueish-grey tones. Creme colours and beige tones dominated the sample selection. Partly, the samples showed natural banded stripes respectively a speckled – mottled appearance. In most cases, a yellowish – white cortex in a thickness range from 0.5 to several mm occurs at both sides of the plates. Sometimes the cortex covers the plates entirely. The cortices surfaces are developed in different ways. One of both cortex surfaces is markedly rougher in terms of haptic sensation. Most likely, this is the original bottom side of the plates. The top of the cortices is of predominantly brownish appearance. At the Rein material, Brandl (2009, 44-45) distinguishes four sub-varieties of tabular chert from the Rein Basin (Rein I – IV, Rein V was added later; see **Fig. 5.1.9. a-e**) and three cortex types (1a, 1b and 2) by means of texture, granularity and the degree of silification (tested with hydrochloric acid), with Rein I representing the poorest material and Rein IV defining high quality chert.

Type variety Rein V is a special case amongst the tabular cherts of the Rein Basin. Rein V is a dark-brown to almost black subvariety of type Rein IV, thus provides excellent knapping properties but is barely present at the raw material spectrum within the known outcrops of tabular chert at the Rein Basin. However, some of the most elaborate stone tools from

Neolithic sites in Styria are made from the Rein V chert variety.

Fig. 5.1.9. a: Rein I; b: Rein II; c: Rein III; d: Rein IV; e: Rein V

Photo: M. Brandl.

Micropalaeontology (MLAS 2)

In literature, a rich fossil content is described from the Rein basin (Peters 1853; Gobanz 1854; Unger 1858; Penecke 1891; Wenz 1923-30; Kubart 1924; Hiden & Rottenmanner 2007). Rock-forming banks consisting of gastropods shells (planorbis mantelli**; Fig. 5.1.10.)** occur within the lacustrine limestones and marls.

Fig. 5.1.10.: *Planorbis Mantelli* **in silicified marl from the Reiner Basin**

Photo: W. Postl.

Fossil inclusions in chert nodules of the Rein 6 and 7type varieties

Thin sections of the nodule investigated by Alker (1979) show characteristic cross-sections of charophytes (*charophytae*), filled in with spherolitically developed chalcedony **(Fig. 5.1.11.)**. According to XRD-analyses, moganite was detected besides quartz. However, the moganite content is situated close to the detection limit.

Charophytes are stoneworts, a division of the green algae family. Stoneworts are submergent plants that are anchored at the bottom of bodies of water with regularly clean and low-nutrient fresh or brackish water. Preferred habitats are calcareous lakes, comparable to the Miocene lake in the Rein Basin. Newest research revealed that stoneworts are able to survive in waters with a salt content of over 70% as well (Tucker & Wright 1990). Charophytes remains are common fossil inclusions in nodular chert from the Rein Basin, however since oogonia – the female reproductive organs of charophyta – are not present, a closer determination of these fossil remains is not possible at the moment.
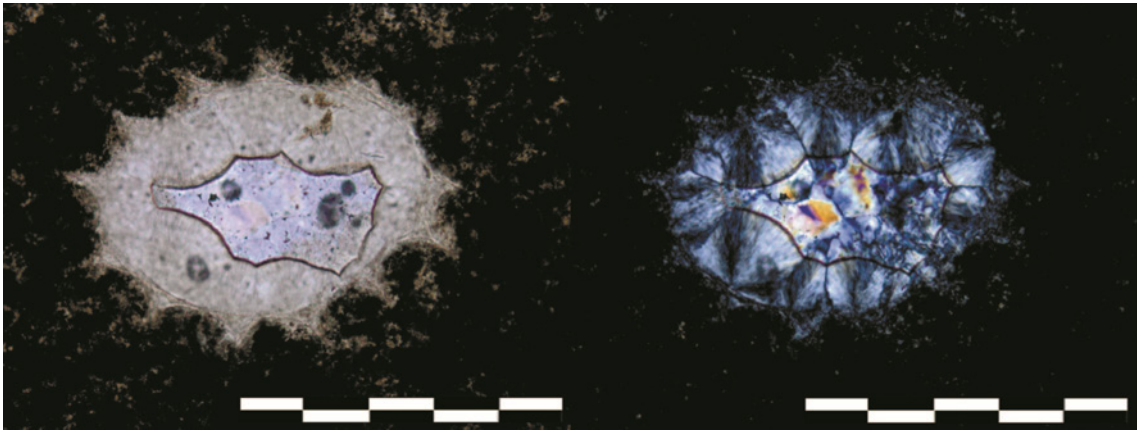
**Fig. 5.1.11.: Thin section with cross section of *charophyta*
in nodular chert from Rein, type variety Rein 7
(left: // polarizers, right: + polarizers)**
Length of the bar: 1 mm. *Photo: W. Postl.*

Fossil inclusions in chert nodules of the Rein 8 type variety

Fossil charophytes remains were recorded occasionally in nodular chert of the Rein 8 type
(Fig. 5.1.12.). In most cases, the preservation is much poorer than at nodules of the Rein 6 and
7 type varieties. Additionally, they are only known from few specimens. However, the overall
appearance of Rein 8 chert is very characteristic even at small sized pieces, so that researchers
familiar with the variability of the material will not get tempted to mistake it with any other
chert variety of the Rein Basin.

Fig. 5.1.12.: Charophyte inclusion in the cortex of a chert nodule of the Rein 8 type
Reflected light microscopy. Length of the bar: 1 mm. *Photo: M. Brandl.*

Fossil inclusions in tabular chert (varieties Rein I–V)

Tabular chert varieties are relatively poor in fossil inclusions. This is most likely due to diagenetic processes in the course of the chertification of lacustrine limestones in the Rein Layers.

Occasionally, remains of snail shells (*Segmentaria nitidiformis*) and various species of smooth-skinned freshwater ostracods (*Condona sp.* und *Cyclocypris sp.*) were found in the Rein chert, mostly included close to the natural surface or in rock parts of poorer quality **(Fig. 5.1.13.)**. Ostracod remains are mainly preserved as characteristic oval-shaped cross sections. However, only few samples contain such characteristic fossil inclusions (Postl et al. 2008b, 113).
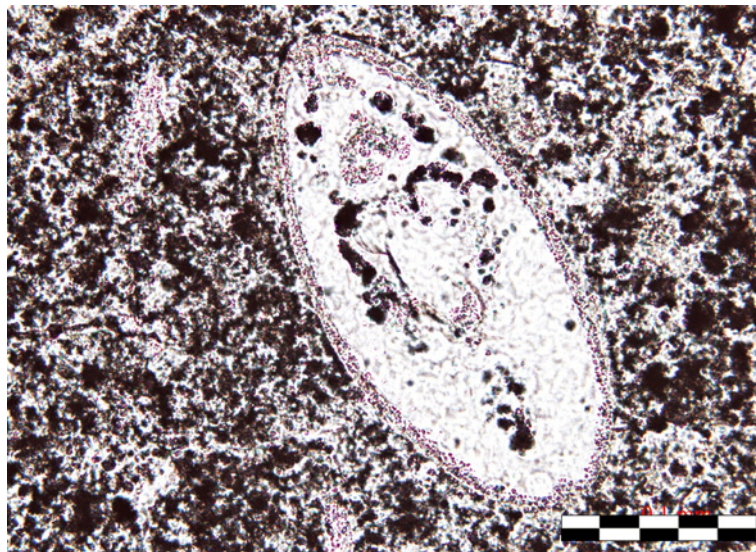
Fig. 5.1.13.: Cross section of a fresh water ostracode
in tabular Rein chert, variety Rein I

Transmitted light microscopy. Lenght of the bar: 0,1 mm. *Photo: W. Postl.*

5.1.3.2. Baiersdorf

Geographical setting

The region around Kelheim/Regensburg, known as the "Altmühl-Alb", is an important area for chert quarrying in southern Germany. One of four quarrying sites within that raw material cluster is the occurrence of tabular chert at the site of Baiersdorf.

The Baiersdorf chert source is situated on a shallow ridge between the villages of Baiersdorf and Keilsdorf, about 25 km west-southwest of Regensburg in Lower Bavaria **(Fig. 5.1.5.)**. The mostly tabular chert occurs at one of the Upper Jurassic basins in the southern Franconian Alb, the so called Paintener Wanne. The supposed prehistoric mining district covers the entire upper part of the ridge, some 35 hectares in all.

The Paintener Wanne basin is one of numerous geological structures in the region, covering an area of approximately 6 km^2 around the name giving town of Painten, 20 km west of Regensburg. It is mostly wooded country on a plateau cut by small streams with an elevation of about 500 m above sea level. The southern border is characterized by a steep slope, descending abruptly 150 metres to the narrow valley of the Altmühl.

Geological setting

The Franconian Alb is one of the major geographical features of Southern Germany. It is more or less the continuation of the Swiss and French Jura Massives, running for about 400 km between the Schwarzwald in the southwest and the Frankenwald region around Bayreuth in the northeast. The region is characterized by a landscape of scarp and vale, with locally steep cliffs of limestone.

A local terminology concerning the geological stratigraphy is used in that region. In place of the international standard division Lower, Middle and Upper Jurassic (Geyer & Gwinner 1984), this period is divided into "Schwarzer" (Black), "Brauner" (Brown) and "Weißer" (White) Jura. These epochs are further subdivided in five stages numbered form α (alpha) to ζ (zeta), which in some cases are again segmented in numbers. In order to indicate the age of a formation, the epoch names Lias, Dogger and Malm are used.

The basis of the geological stratigraphy in the Paintener Wanne is formed by Massenkalken of the Kelheim facies. On top of that formation follows a neogene loamy unit referred to as

"Albüberdeckung". In the upper parts of the Albüberdeckung, packages of weathered laminated cherts occur in a loamy matrix. According to the local terminology, these so called "Sandwich-plates" were formed in Malm ζ, which correlates with the Upper Jurassic stage of the Thitonian (Moser 1978; Binsteiner 1987; Binsteiner 1989; Binsteiner 1990; Binsteiner 2001; Binsteiner 2005). Besides the well known tabular varieties, chert nodules occur within the Baiersdorf deposit as well (Binsteiner 2005, 55).

Tabular chert from Baiersdorf – macroscopical description (MLAS 1)

The chert samples originating from the Baiersdorf source reach a thickness ranging between 12 and 25 mm. The variation of colour ranges from creme coloured-beige to light brown and bluish-grey. Irregularly banded stripes and speckled colour sequences are common features of that raw material **(Fig. 5.1.14.)**. The whitish-light brown cortex covers both sides of the plates and can reach several mm in thickness. The difference between upper and bottom side is more significant than at the Rein samples. The rough (bottom) side shows cavernous, partly warty shaped areas. The upper sides are predominantly auburn coloured. Nodular chert from Baiersdorf is much rarer and can reach diameters of over 30 cm, however the majority does not exceed 10 cm.

Fig. 5.1.14.: Tabular chert from the Baiersdorf chert deposit *(Photo: M. Brandl).*

Micropalaeontology (MLAS 2)

It is well known from previous studies, that this tabular chert is only rich in fossil inclusions close to the cortex areas (Binsteiner 2005, 98). In the present study, only some unidentifiable remains of marine organisms with grain sizes ranging from 5 to 20 µm and marine detritus were detected in the Baiersdorf chert **(Fig. 5.1.15.)**. The only clearly determinable inclusions are residues of shells and echinodermata, and in rare cases spicula **(Fig. 5.1.16.)**. Fossil inclusions within Baiersdorf cherts regularly only occur close to the cortex region. The core material shows only very scarce fossil contents, which is also assignable to diagenetic processes.
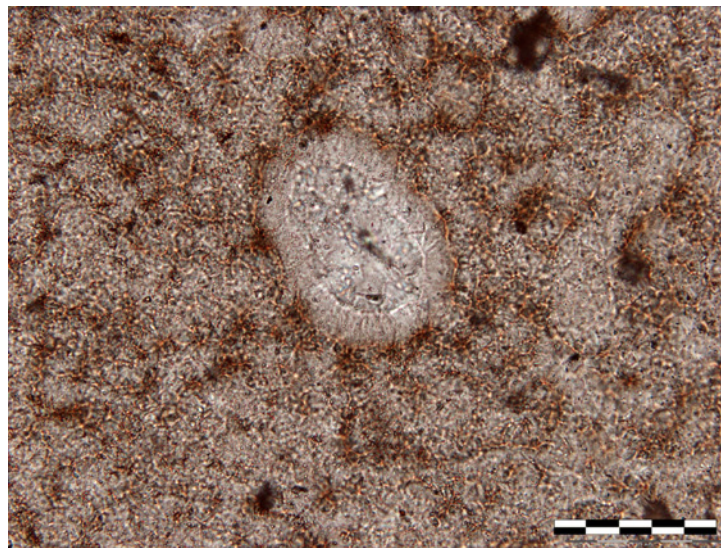
Fig. 5.1.15.: Marine detritus in tabular Baiersdorf chert
Transmitted light microscopy. Length of the bar: 0,1 mm. *Photo: W. Postl.*
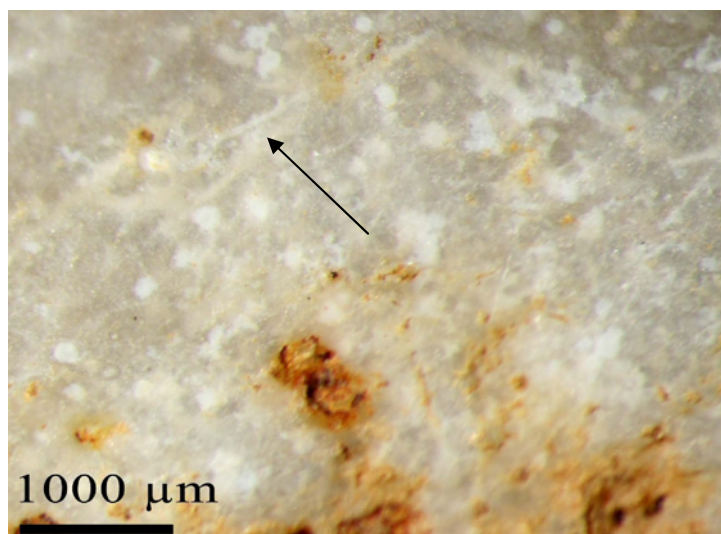
Fig. 5.1.16.: Spicula in tabular Baiersdorf chert (*arrow*)
Reflected light microscopy. Length of the bar: 1 mm. *Photo: M. Brandl.*

The most distinctive difference between the chert from Rein and Baiersdorf is the genesis environment of the host rock facies. The Baiersdorf material was formed under marine conditions, whereas the Rein chert is of lacustrine origin. A direct comparison is provided in **Table 5.1.4.**

Chert source	**Baiersdorf**	**Rein**
Location/ Geological Unit	Franconian Alb, Paintener Wanne	Styrian Neogene-Basin, Rein Basin
Geological stage	Upper Jurassic Thitonian/Malm ζ	Neogene, Miocene Lower Badenian
Period in Ma	150.8–145.5	16–13.3
Stratigraphy		
Basis	Massenkalke, Kelheim facies Loamy „Albüberdeckung"	Limnic units (Badenian), Rein Layers
Upper part	On top: Package of weathered laminated cherts in loamy matrix („Sandwich-plates")	Linked to these layers: Tabular chert within lacustrine carbonates in the upper parts of the Rein Layers
		Chert occurrence: Rein Basin at an elevation up to 440m
Petrology	Silicified **marine** sediments	Silicified **freshwater** carbonates

Table 5.1.4.: Comparison between the genesis conditions of Rein and Baiersdorf chert

Graph: M. Brandl.

5.1.4. Mineralogical, petrographical and geochemical investigations (MLAS 3)

In the course of the revision of the Repolust Cave assemblage, scientific analysis was conducted on Rein chert.

Mineralogical investigations were carried out at the Department of Mineralogy at the Universalmuseum Joanneum at Graz. In a first step, polished sections and thin sections (0.03 mm) of selected chert samples have been produced. The mineral content was determined

applying X-ray diffractometry, in some cases additional IR-spectra have been produced.

Rock surfaces of 22 samples – 11 from Rein and 11 from Baiersdorf – were investigated with the SEM unit at the Department for Earth Sciences, Karl-Franzens University Graz, in order to obtain high resolution images and to analyse the chemical composition of the occurring mineral phases in the chert samples.

Eventually, geochemical investigations were carried out using LA-ICP-MS at the University of Graz, Institute of Chemistry-Analytical Chemistry.
The sample size from the Rein source counted 28 microflakes, 22 pieces were analyzed from the Baiersdorf occurrence. All samples measured 2x2 mm in average.

5.1.4.1. Mineralogical/petrographical characterisation of Rein and Baiersdorf chert

Macroscopically, the tabular varieties from both occurrences are nearly similar **(Fig. 5.1.17.)**. For the most part, the coloration, the haptic perception, fracture characteristics and knapping properties are nearly identical. Slight differences can only be detected in the texture of the cortex and the edging of the chert plates. Ordinarily, at the Baiersdorf chert the cortex is coarser and yellower than the cortex of the Rein chert. Additionally, the edges of the plates from Baiersdorf end sharp and splintery, while the ones from Rein are often rounded and covered in cortex.
Profiles showing clearly defined layers of different coloration were documented at both sample series **(Fig. 5.1.18.)**. Nevertheless, both reflected- and transmitted light microscopy investigations showed basically no potential for a differentiation between the two raw materials according to those optical divergences. Surface character, the porosity and general characteristics are too similar to make results conclusive. Only in the case of fossil inclusions a clear discrimination is possible.

The X-ray diffraction analysis only revealed quartz at both the Rein and the Baiersdorf samples. Few of the Baiersdorf samples contain a small amount of calcite in the cortex region. Nevertheless, this observation is not suitable for a differentiation. The components of Moganite, Tridymite and Opal-CT are below the detection limit.
Additional to that, the IR-spectroscopy revealed that amorphous phases (Opal-A) level below

the analytical limit as well. The analytical results from SEM investigations confirm the results from XRD and IR-spectroscopy. All samples consist of micro crystalline quartz in a micro-granular pattern. The only difference is a slightly larger grain size, partly a slight gradation and – according to XRD results – carbonates at the cortex region of the Baiersdorf cherts.

Mineralogical-petrographical results did not deliver significant results and thus did not allow for a clear distinction between the Baiersdorf and the Rein samples. Consequently, the research mainly focussed on the geochemical approach applying LA-ICP-MS.

Fig. 5.1.17.: Macroscopic (visual) comparison
between tabular Rein (l) and Baiersdorf (r) chert
Length of the bar: 5 cm. *Photo: W. Postl.*
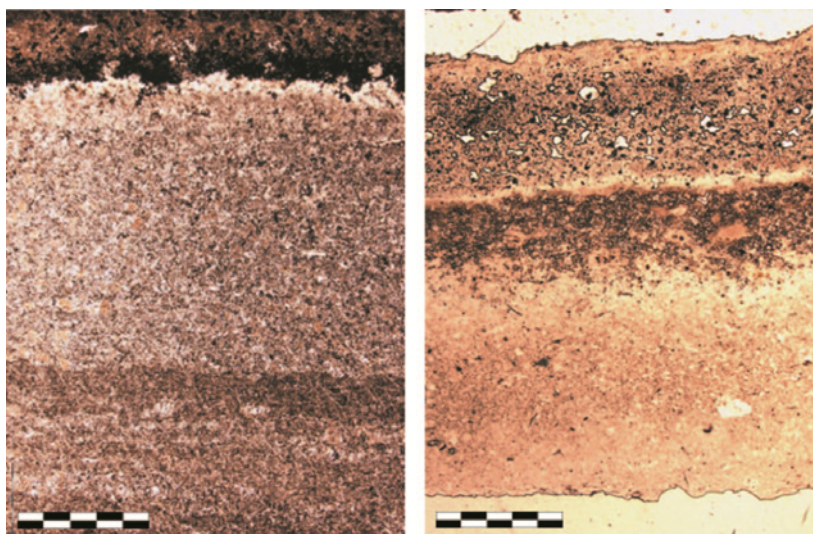
Fig. 5.1.18.: Thin sections of Rein (l) und Baiersdorf (r) chert samples
Length of the bar: 0,1 mm. *Photos: W. Postl.*

5.1.4.2. Geochemical analysis

Trace element analysis at the University of Graz clearly demonstrated that geochemistry is the method of choice for the present case study. Geochemical parameters like lithium (Li), boron (B) and to a lesser extent aluminium (Al), titanium (Ti), vanadium (V), strontium (Sr), rubidium (Rb), copper (Cu) and zinc (Zn) were found to be useful in distinguishing samples from Rein and Baiersdorf.

To a certain degree, a distinction is possible using the elements Ti and Al **(Fig. 5.1.19.)**, a clear discrimination is achieved by the elements Li and B **(Fig. 5.1.20.)**. The trace elements V, Sr, Rb, Cu, and Zn also allow a separation between the two deposits. However, these elements occur partly at very low concentrations (< 1 mg/kg), which is close to the detection limit of the applied method.

The low lithium and boron contents in the samples from Rein can be explained by the lacustrine origin of the cherts compared to the marine origin of the Baiersdorf chert deposit. Sea water contains about 0.17 mg/kg Li and 4.5 mg/kg B while fresh water has 0.003 mg/kg Li und 0.01 mg/kg B (Taylor & McLennan 1985). Thus, the deposited cherts inherited these significant differences in Li and B concentrations. The measured Li and B contents differ between the samples from Rein and Baiersdorf by one order of magnitude.

In contrast, the elements Fe, Mn, Cr and Ni turned out to be unusable for any discrimination **(Fig. 5.1.21.)**. The content of these elements vary with the color of the chert. Brownish and black areas are enriched in these elements, independent of the origin of the chert samples (also compare Rottländer 1975; Andersen & Whitlow 1983).
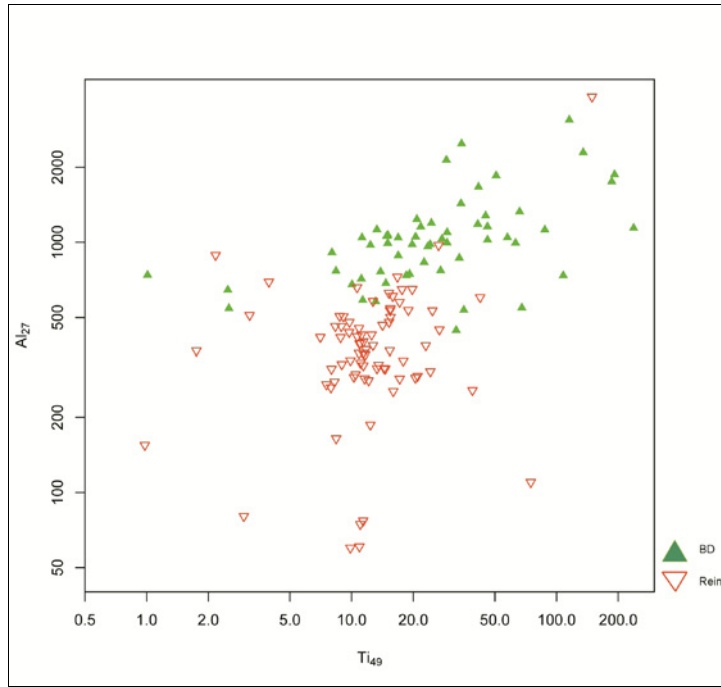
Fig. 5.1.19.: Titanium versus aluminium concentration plot of the Baiersdorf and Rein samples[7]
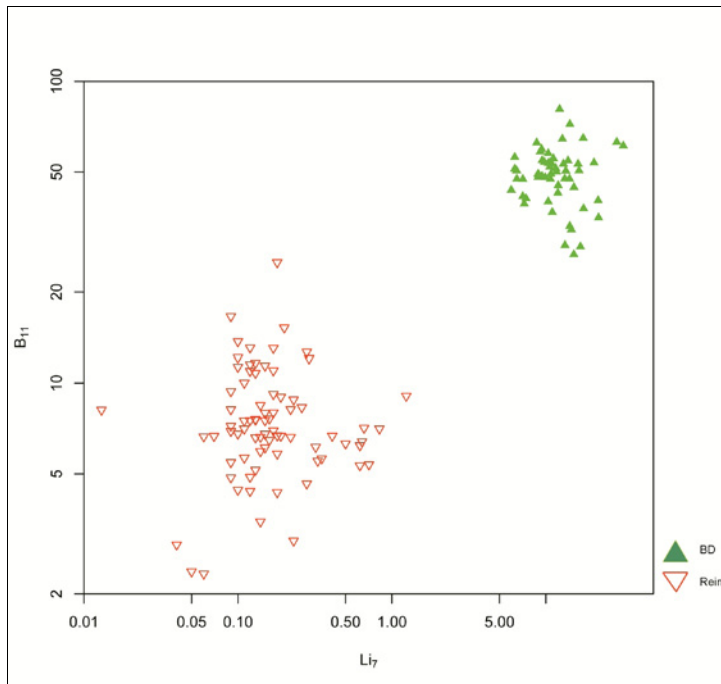
Fig. 5.1.20.: Lithium versus boron concentration plot of the Baiersdorf and Rein samples

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[7] All plots by M. Brandl.
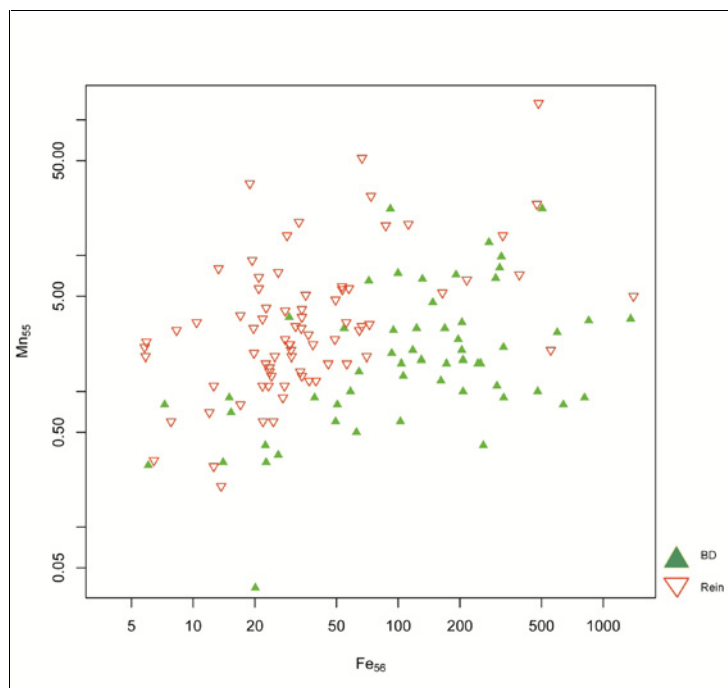
Fig. 5.1.21.: Iron versus manganese concentration plot of the Baiersdorf and Rein samples

5.1.4.3. Application of the results to archaeological material

This first essential phase achieved, the results were applied to archaeological finds. At first, the chert finds from the Repolust Cave were investigated. Subsequently, stone tools from important Neolithic sites in Styria and from one Carinthian site were included into the provenance studies **(see Tab. 5.1.4.** and **Fig. 5.1.22.)**.

No. in map	site	dating	raw material	sample no.
1	Repolust Cave	Middle Palaeolithic	nodular chert	78
2	Tunnel Cave	Palaeolithic	nodular chert	4
3	Zigeuner Cave	Late Palaeolithic/ Late Neolithic	nodular chert/ tabular chert	9
4	Kanzelkogel	Late Lasinja– Hocevarica	tabular chert	1
5	Oberandritz	Late Neolithic	tabular chert	8
6	Raababerg	Lasinja/ Retz	tabular chert	12
7	St. Ulrich am Waasen	Lasinja/ Retz	tabular chert	3
8	Weitendorf/ Koralmbahn	Lasinja	tabular chert	3
9	Tesserriegel	Lasinja	tabular chert	11
10	Gnas/ Sandriegel	Lasinja	tabular chert	1
11	Betenmacherkogel	Spätlasinja	tabular chert	7
12	Dietenberg	Lasinja and later	tabular chert	2
13	Stainz/ Lethkogel	Lasinja–Mondsee	tabular chert	1
14	Glaserkogel	Lasinja	tabular chert	4
15	Noiberg	Lasinja; Somgyvar/ Vincovcy	tabular chert	4
16	Grötsch	ca. 800 AD	tabular chert	2
17	Strappelkogel (Lavanttal)	Late Neolithic	tabular chert	1
			total:	151

Table 5.1.5.: List of the sampled sites containing Rein chert

Graph: M. Brandl.
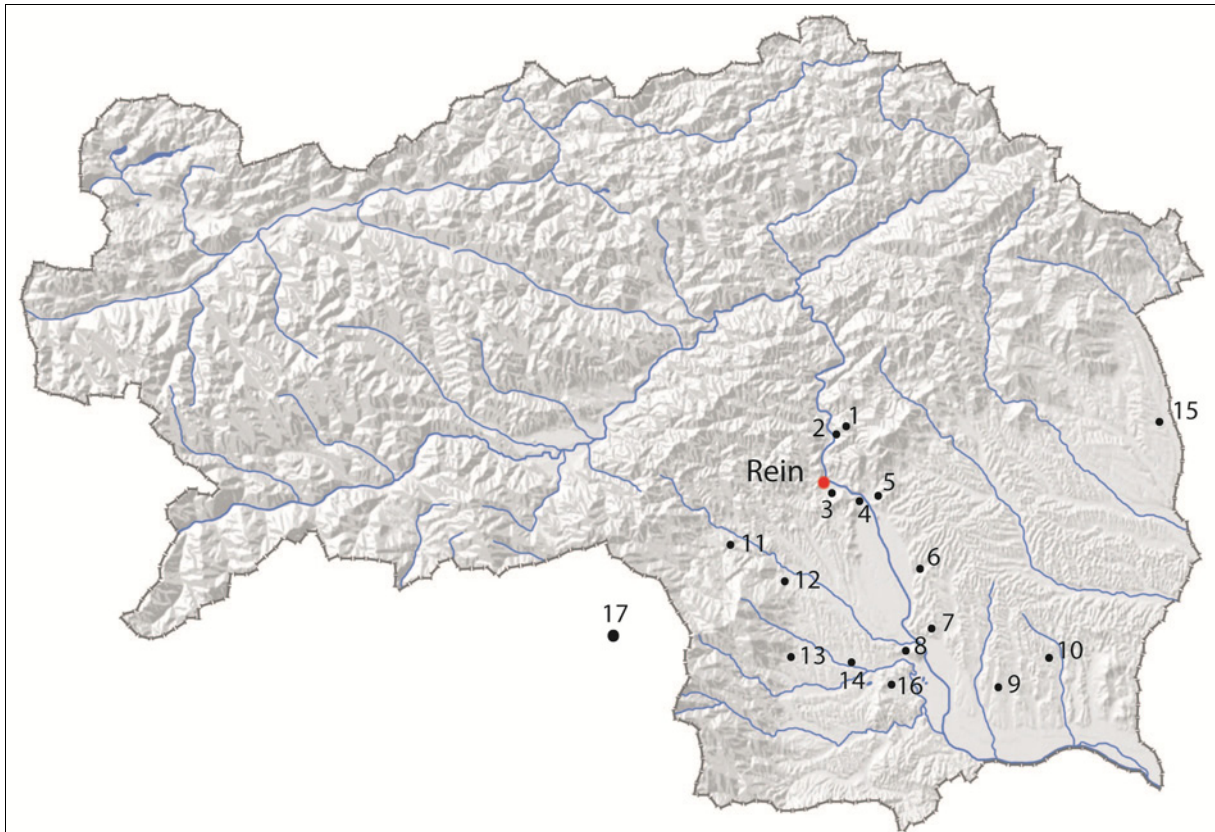
Fig. 5.1.22.: Location of the investigated sites containing Rein chert

No. 17 is situated in Carinthia

Graph: M. Brandl.

5.1.4.3.1. The Repolust Cave chert assemblage

The Repolust Cave is located at the south-easternmost rim of the Inner Alpine region, in the Middle Mur Valley, on the northern side of the so called "Badlgraben" near Peggau **(Fig. 5.1.22.)**. At the Repolust Cave site, the remains of hunter and gatherer stations dating to the Middle Paleolithic period have been preserved. The site is well known for holding evidence of the earliest traces of human activities in the region during the last ice age. Several excavation campaigns produced the most substantial paleolithic find complex known from an Eastern Alpine cave site.

Altogether, the Repolust Cave find complex consists of nearly 1700 lithics, 1058 quartz and quartzite samples and 629 cherts. Unfortunately, the lithic finds do not significantly contribute to chronological issues. In the course of a preliminary overview, the lithic industry was classified as Tayacian respectively Clactonian (Mottl 1975, 46), recent investigations point in

the direction of an undifferentiated Middle Paleolithic assemblage. The lithics recovered in the horizontal passage were bound to a "grey sand layer" and an "auburn phosphate layer", however their spatial distribution within those two main layers is not reconstructable. They can be divided into manuports, flakes, debris, cores and a group of tools mainly showing lateral retouching. Whilst the quartz and quartzite raw material most likely originates from Mur river gravel bars, the provenance of the chert remained unknown (Mottl 1975, 46).

In the course of the revision of the Repolust Cave finds in 2009, all 598 chert artifacts from the Repolust Cave stored at the Universalmuseum Joanneum were microscopically analysed. The focus was on specific inclusion patterns and general characteristics of the raw material. Micropictures (**Fig. 5.1.23.**) were produced in order to create a comparative database. Different stages of patination and surface alteration were observed and documented additional to scratch traces and adherent sediment remains.
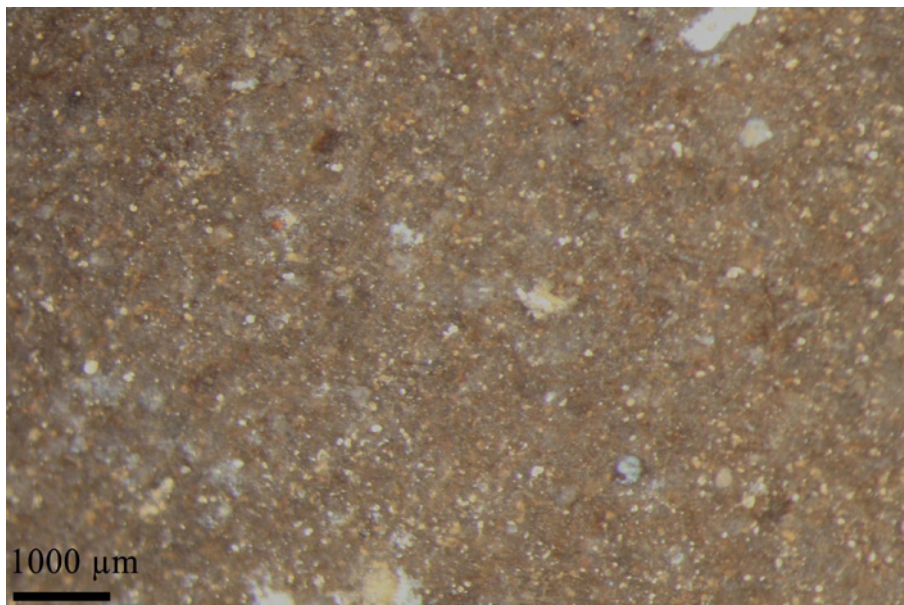
Fig. 5.1.23.: Characteristic surface structure of a chert artifact from the Repolust Cave (Inv.No. 15396)

Reflected light microscopy. Length of the bar: 1 mm. *Photo: M. Brandl.*

These investigations revealed nodular chert as the predominant raw material of the assemblage. Only four specimens (InvNo. 15360, 15.709, 16.043 and 24.838) are produced from tabular chert **(Fig. 5.1.24.)**. The original size of most of the nodules used for the production of the Repolust Cave stone tools could be reconstructed to diameters ranging

between 10 and maximal 20 cm. Assertions concerning microscopical analysis were constrained by the lack of suitable comparative material. Thus, natural scientific analysis methods gained major importance for a determination of the chert source provenance.

**Fig. 5.1.24.: Artifacts from tabular (l) and nodular (r) chert
from the Repolust Cave** *(Photo: D. Modl).*

Altogether, 78 artifacts from the Repolust Cave were sampled by W. Postl and M. Brandl and analyzed by LA-ICP-MS. Sampling was conducted as careful as possible, with the focus on taking preferably homogenous rock parts for analysis.

As shown above, a distinction of the sources at Rein and Baiersdorf can be achieved looking at the lithium (Li) and boron (B) content. Although a provenance of the Repolust Cave cherts from Baiersdorf was never seriously considered (on account of the nodular form of the raw material), all doubts had to be removed and – most important – possible conformities with the Rein material should be examined.

The data collected from the Repolust Cave cherts clearly overlap the cluster produced from samples from the Rein basin **(Fig. 5.1.25.)**. The samples from the Repolust Cave show slightly higher Li-values compared to the raw material samples from Rein on average.

A possible explanation is the sample material used for the characterisation of the Rein chert. For this analysis, only tabular chert was available, whereas the Repolust Cave material is made from nodular chert. The rediscovery of the well shaft at Rein Hart containing chert

nodules identical to those from the Repolust Cave has shown that both occurrences are situated within a considerably small area only a few hundred meters apart, and that both the tabular and the nodular chert variety are therefore geochemically nearly identical.
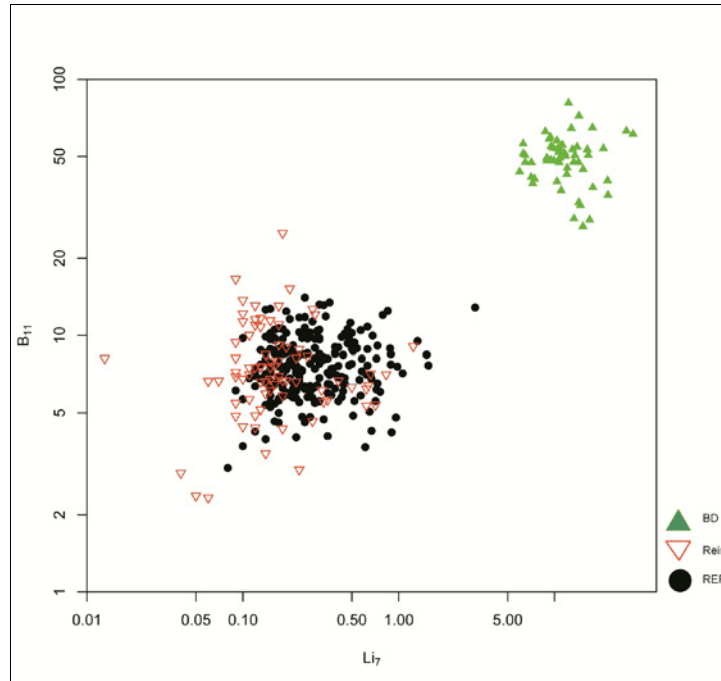
Fig. 5.1.25.: Lithium versus boron concentration plot of the Baiersdorf, Rein and Repolust Cave samples

Additional to lithium and boron, titanium, aluminium, strontium and vanadium were used for a further classification of the archaeological objects. Titanium and aluminium did not turn out to be distinctive in the case of the Repolust Cave finds. All three clusters overlap insignificantly **(Fig. 5.1.26.)**. A better determination can be achieved looking at the Sr and V contents. These elements show a higher accordance of the Repolust cherts to the Rein data **(Fig. 5.1.27.)**.The Rein cluster demonstrates a low ratio average in both Sr and V contents. Baiersdorf cherts mainly contain much higher V contents than the Rein samples. The Sr – concentrations are slightly higher at the Baiersdorf source. The bulk of the data gained from the Repolust Cave samples coincides with the main cluster from Rein. Some outliers have considerably higher values than both Rein and Baiersdorf (Brandl et al. 2011, 61-62).
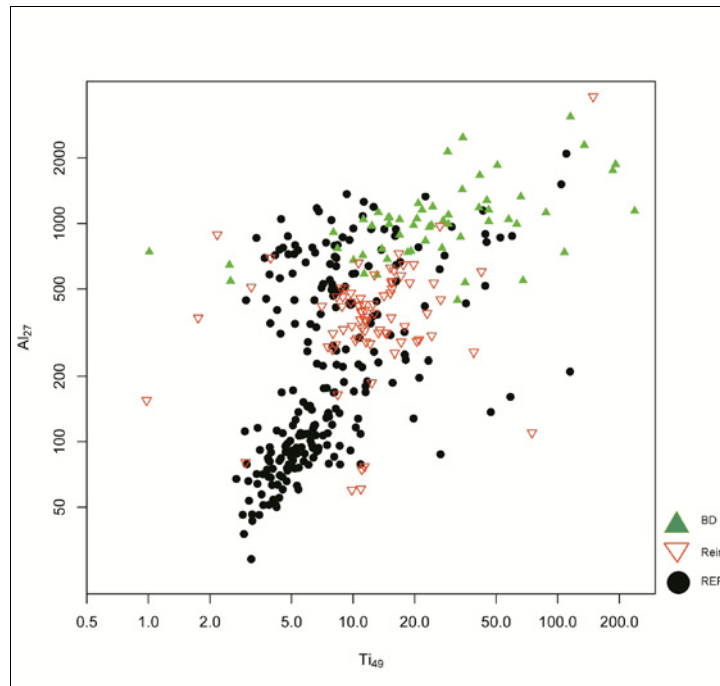
Fig. 5.1.26..: Titanium versus aluminium concentration plot of the Baiersdorf, Rein and the Repolust Cave samples
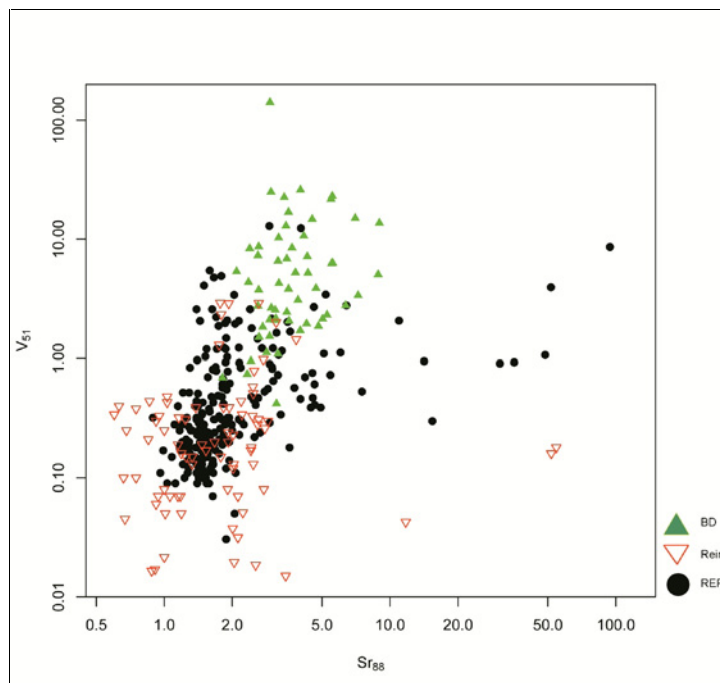
Fig. 5.1.27..: Strontium versus vanadium concentration plot of the Baiersdorf, Rein and the Repolust Cave samples

In the course of the possibility to examine some rare specimens of the nodular chert variety from Rein, further evidence for an origin of the Repolust Cave finds in the Rein basin was found. Thin sections of some artifacts were produced. They show characteristic cross sections of charophytes (*charophytae*) filled with spherolitic developed chalcedony. As mentioned above, identical sections were detected in the nodular chert sample from Rein (thin section, Inv.No. 41837, petrographic collection Department of Geosciences, Universalmuseum Joanneum; **Fig. 5.1.11.** and **Fig. 5.1.28.**) investigated by Alker (1979).

Besides quartz, moganite was detected via long-time XRD measurement in both, chert samples from Rein (tabular and nodular varieties) and selected samples from the Repolust Cave. The moganite content is at the limit of detection in tabular and nodular Rein chert as well as in the Repolust Cave artifacts. In direct comparison, the chert nodule investigated by Alker (1979) from Rein and representative chert samples from the Repolust Cave show some differences. Most important, the Repolust Cave finds do not contain traces of tridymite and dolomite, which is characteristic for the Rein Hart nodules.

In addition to tabular and nodular samples from Rein (varieties I–IV and 6– 7), specimens of the Rein 8 type variety were included into the LA-ICP-MS analyses. Lithium (Li) and boron (B) contents are clearly situated within the Rein data cluster **(Fig. 5.1.29.)**. However, both visual (macroscopic) and microscopic properties of Rein 8 show grave differences to the Repolust Cave cherts, precluding an origin of the archaeological material from the Rein 8 chert source at the Rein Basin. The best accordance is seen between the Repolust Cave finds and the Rein 6/7 type varieties from the well shaft at Rein Hart. Present investigations are focussed on the actual outcrop at the Rein Basin utilized for raw material procurement at the time the Repolust Cave find horizons were formed (Brandl et al. 2011, 54-55).
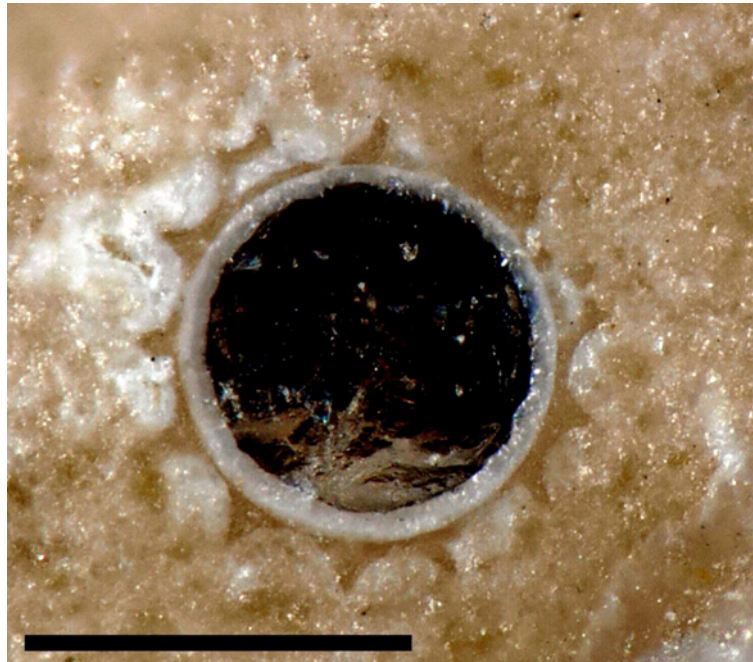
Fig. 5.1.28.: Thin section of the chert nodule from Rein Hart

investigated by Alker showing a charophyte cross section

Reflected light microscopy.Length of the bar: 1 mm. *Photo: W Trattner.*
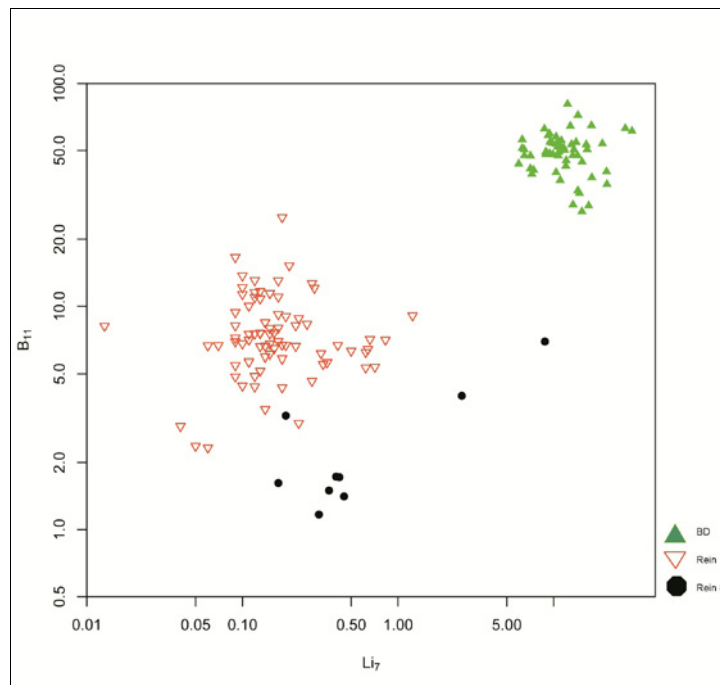
Fig. 5.1.29.: Lithium versus boron concentration plot of the samples

from Baiersdorf, Rein and the Rein 8 chert variety

5.1.4.3.2. Supplemental assemblages from Styria and Carinthia

In total, 17 archaeological sites were analysed in addition to the Repolust Cave finds. Two sites are Palaeolithic, 14 are Neolithic and one site dates to Early Medieval times. Sixteen of those sites are located in present day Styria, and one site is situated in Carinthia **(Fig. 5.1.22. and Table 5.1.5.)**. Besides research questions concerning the distribution of Rein raw material, an additional focus was laid on the chronological depth of the exploitation of the Rein chert deposit. For this undertaking, assemblages containing chert macroscopically identical to Rein material and covering a time span from the Palaeolithic to the Early Medieval were chosen.

5.1.4.3.2.1. Palaeolithic sites

Besides the substantial Repolust Cave assemblage, Palaeolithic chert artifacts visually corresponding to Rein raw material were recovered at the Tunnelhöhle (Tunnel Cave; Fuchs & Ringer 1995; Derndarsky 2009),) in the Middle Mur Valley and at the Zigeunerhöhle (Zigeuner Cave; Pittioni 1955, 12-24; Antl 1995, 41-42) near Gratkorn, both situated in Styria **(Fig. 5.1.22.)**. The Tunnel Cave finds date to the Middle Palaeolithic; the Zigeuner Cave contained two archaeological layers, with the upper layer dating to the (Late) Neolithic and the lower level dating to a late phase of the Late Upper Palaeolithic. Chert artifacts from that lower level were investigated for comparison studies.

Both Palaeolithic find complexes mainly consist of nodular chert, supporting the idea that Palaeolithic assemblages in Styria primarily contain that particular type of raw material. Geochemical analyses have revealed the provenance of the cherts macroscopically and microscopically assigned to the Rein chert source from this deposit, since the data points are clearly situated within the Rein data cluster **(Fig. 5.1.30.)**.
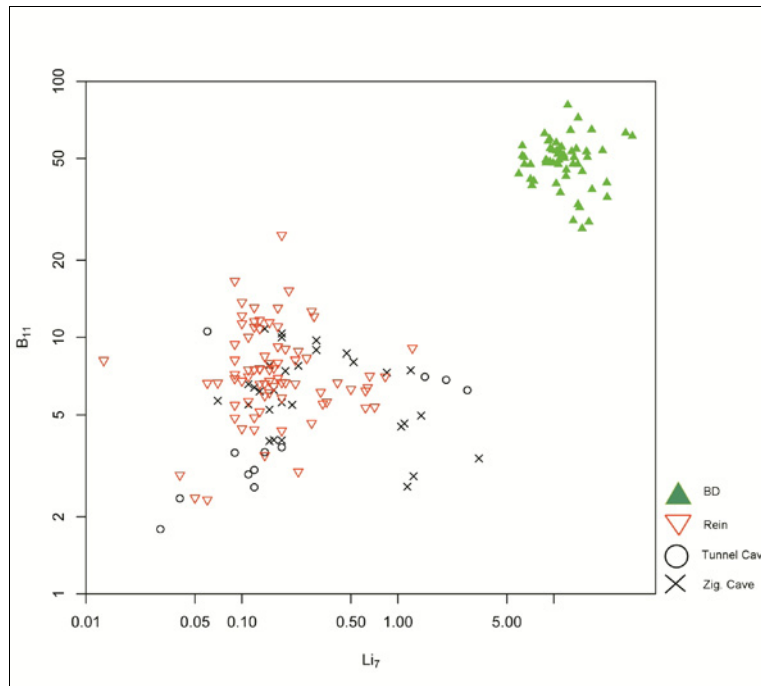
Fig. 5.1.30.: Lithium versus boron concentration plot of the samples from Baiersdorf, Rein, the Tunnel Cave and Zigeuner Cave assemblages

5.1.4.3.2.2. Neolithic sites

The sites chosen for comparison studies do not date to the same Neolithic stage. They present a fine-chronological range, however they provide a useful overall view concerning the state of research concerning the Neolithic in Styria (without the claim of completeness).

In the course of the ongoing investigations, a chert artifact from the Strappelkogel in the Lavanttal (Carinthia) was included. The private collector Dr. Andreas Hassler (St. Andrä in the Lavanttal) provided the find for analysis.

In most cases, the investigated sites are hilltop settlements dating to Neolithic stages, however geographical position and topography are secondary to the present study and have already been described in detail by Obereder (1989), Brandl (2009) and Dolenz (1955).

Except for the Carinthian site, all Neolithic Styrian chert assemblages contain the initially mentioned white-grey non-translucent tabular chert. This tabular Rein-type chert can be defined as the "index fossil" for Neolithic find complexes in Styria, in some cases even constituting the main percentage of the lithics.

The fall-off curve for the distribution of this "index"-chert in Neolithic assemblages from Styria **(Fig. 5.1.31.)** is determined by the link between the count of chert artifacts from Rein

material and the distance of the archaeological sites from the chert source. Divergences are explained by the small amount of find material in some of the investigated sites and possibly due to chronological reasons in others (Brandl 2009, 92-93). These arguments exclude an interpretation of the curve as an indication for Renfrew's (1972) "directional trade"-exchange mode. A clear tendency of a decreasing amount of Rein chert in Neolithic sites in Styria directly proportional to the distance of the sites from the source is statistically evident.
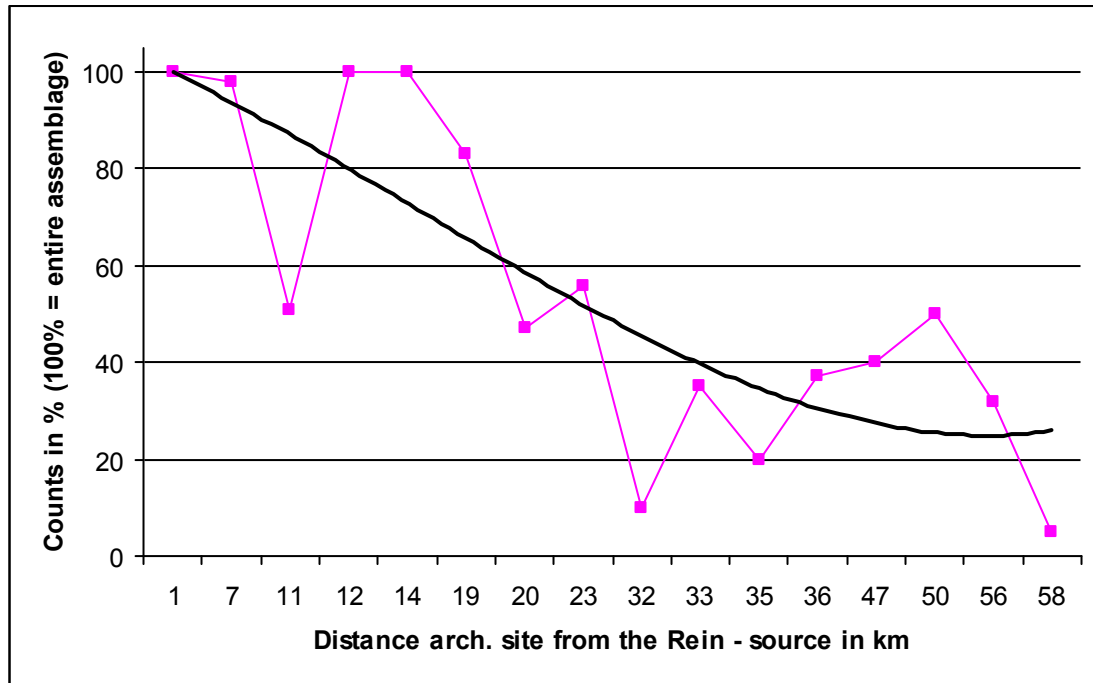
Fig. 5.1.31.: Fall-off curve for tabular Rein chert
in Neolithic assemblages from Styria
Graph: M. Brandl.

Geochemical results support the premise that the tabular "index"-cherts from Neolithic sites in Styria and the Carinthian specimen originate from the Rein Basin **(Fig. 5.1.33.)**. The successful excavation in 2010 did not only reveal the first proof of the long presumed mining of the tabular chert variety in the Rein Basin, but allowed for a localization of the actual mining area.

The question, whether or not some specimens from Styrian sites originate from Baiersdorf still remains to be resolved, due to the fact that it was impossible to investigate 100% of the find material. At the present state of research, it seems rather unlikely. The spectrum of stone tools at Styrian sites is entirely different than typical lithic artifacts produced from Baiersdorf material. Similar forms do occur, however the Styrian lithics are considerably smaller

compared to, e.g., artifacts from the Altheim group. This is partly due to the quality of the available raw material at the Rein Basin. These assessments are based on characteristic tools, mainly sickle blades. Additionally, in contrast to Rein raw material, Baiersdorf chert was never used for flake industries to a large extent

5.1.4.3.2.3. Early Medieval finds

Two chert tools from the necropolis of Grötsch (St. Nikolai in Sausal, Leibnitz district, early 9th century AD, InvNo. 18.587 and 18.588; see **Fig. 5.1.22.**, No. 16 and **Plate 1.3.** in **Appendix D2**), stored at the collection of the Universalmuseum Joanneum, show strong visual similarities with Rein raw material (Type Rein I/II). Additionally, inclusions of shell remains of Planorbis-snails supported the suspicion of an origin from Rein **(Fig. 5.1.32)**. According to artifact-morphological criteria and due to the presence of oxidized iron traces (rust) at protruding parts of the rocks, their function was determined as strike-a-lights. The assumption, these artifacts originate from the Rein source, was eventually verified by LA-ICP-MS analysis **(Fig. 5.1.33.)**.

Fig. 5.1.32.: Chalcedonized *Planorbis Mantelli*-shell
from artifact 18588 from Grötsch
Photo: M. Brandl.

If these findings prove rare procurement practices of Rein chert up to Early Medieval times, or if they are reused Neolithic artifacts remains uncertain. However, it is conspicuous that

both strike-a-lights are made from raw pices of chert, which makes an assessment whether or not they were directly obtained from the Rein Basin or if they were collected from aNeolithic site almost impossible. Thus far, younger finds, e.g., gunflints, are not known from Rein chert.
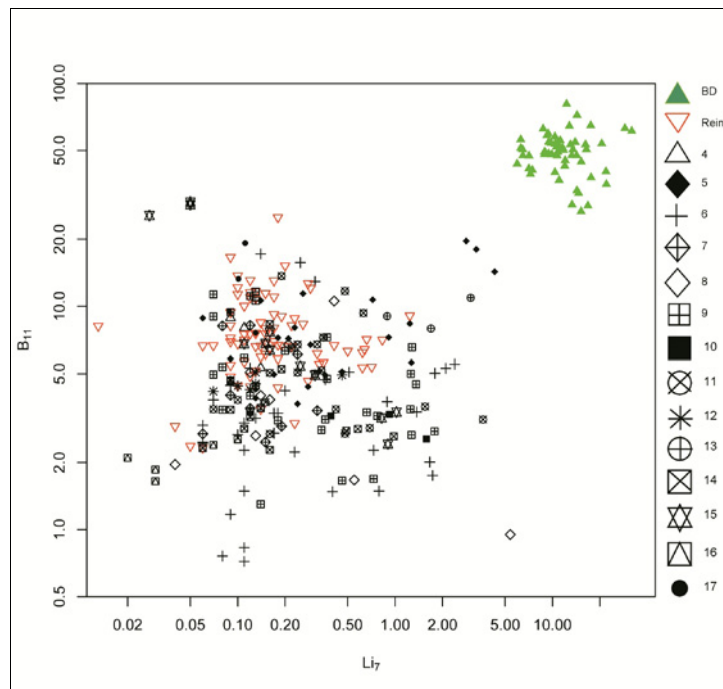
Fig. 5.1.33.: Lithium versus boron concentration plot of the samples from Baiersdorf, Rein and the Neolithic/Early Medieval sites in Table 5.1.5.

5.1.5. Discussion

Due to the geographical position of the Rein chert deposit, a provenance from this source was hypothesized for both, the nodular chert finds from Palaeolithic sites and tabular chert varieties from Neolithic assemblages in Styria. The macroscopic appearance of Styrian chert artifacts (nodular and tabular) from sites of different chronological position matches with the Rein raw material evidently. However, chert nodules used for the production of the Repolust Cave stone tools are markedly smaller-dimensioned than the comparative samples from the Rein Hart well shaft. As mentioned earlier, an origin of the Repolust Cave finds from the Baiersdorf deposit was considered more than unlikely. This was far less certain in the case of the tabular, predominantly Neolithic chert artifacts from Styrian and Carinthian sites, especially since Baiersdorf chert was widespread and very popular in Late Neolithic times (Binsteiner 1989, 331-337).

On that account, data from the Baiersdorf chert samples were incorporated into the comparison study in order to verify and monitor the analytical results.

Since the microscopical, petrographical and mineralogical investigations did not deliver significant results differentiating the Rein and Baiersdorf chert sources, the application of LA-ICP-MS was decided.

A differentiation between the Rein and Baiersdorf chert sources was possible due to the fact that the Baiersdorf source is of marine origin, whereas the Rein deposit is a lacustrine formation. The geological settings are represented by the high divergence in the Li and B contents of the cherts clearly distinguishing the samples.

Based on the geochemical results, the initial assertion – that the Repolust Cave cherts and lithics from Palaeolithic/Neolithic Styrian and Carinthian sites macroscopically similar to Rein chert originate from the Styrian raw material source – is strongly supported by the Li and B contents in the chert material.

Tendentially, the Repolust Cave cherts show higher Li and Sr values than the Rein cluster. An explanation may be found in the natural range of the collected raw material samples or in geochemical processes that took place during the course of the deposition in the cave and slightly influenced the composition of the artifacts (Luedtke 1992; Howard 2002; Burronia et al. 2002; Hughes 2010).

Furthermore, in the case of the Repolust cave finds it has to be taken into consideration that the source material was nodular chert, whereas geochemical analysis was conducted on tabular chert samples. This was due to the fact that chert nodules from Rein were not available at the time of the principle investigations. In general, the chemical composition of chert plates and nodules largely correspond, and slight divergences of the Li- and B-contents can be best explained by the naturally occurring range within the Rein chert source.

The possibility of an origin from a different, not yet known source seems unlikely due to the accordance of other trace element concentrations like Sr and V in the Rein samples and the archaeological chert finds.

In the course of extensive survey activity concerning Styrian chert sources, the possibility of chert occurances in the Western Styrian Neogene Basin has been subject of thorough investigations. The surveys covered the entire catchment area and produced no evidence of further chert outcrops (Brandl 2009, 46). This needs to be set into perspective due to the small

possibility that sources once accessible vanished without leaving a trace during long time periods.

At the state of the art, we assume that – aside of the Baiersdorf deposit – the Rein Basin is the only considerable chert source in the catchment area, and that Rein supplied south-eastern Austria with tabular chert. Based on these results, the origin of the 78 sampled brownish white, non transparent chert flakes of the Repolust Cave assemblage, the artifacts from the Tunnel Cave and the Zigeuner Cave, as well as the tabular cherts from the investigated Neolithic sites and the Early Medieval strike-a-lights from the Rein Basin chert source seems to be assured.

Ongoing investigations are dedicated to the precise location of the outcrops of nodular chert used for stone tool production at the Repolust Cave and other Styrian cave sites (varieties Rein 6 and 7). Furthermore, the complete excavation of the quarrying pit detected in 2010 holding evidence for Neolithic mining of the tabular Rein chert is the priority assignment for the near future.

5.2. Radiolarite studies: Northern Alpine vs. Carpathian sources

5.2.1. Introduction

Radiolarites with exceptional knapping properties occur regularly at Upper Palaeolithic sites in Lower Austria (e.g., Montet-White 1991, 219; Einwögerer 2003, 88; Binsteiner et al. 2008, 185-190). The investigation concerning the provenance of such radiolarites from Upper Palaeolithic sites reignites an old problem, more specifically, questions regarding the use and distinction between Northern Alpine and Carpathian sources. Most researchers assert that high quality radiolarites were not available within the spectrum of river gravels from alpine catchment areas (e.g., from the Danube river) in Lower Austria during Palaeolithic times. Conversely, the Carpathian Mountains deliver such excellent radiolarites, sparking a debate concerning the role this source region played in Palaeolithic raw material procurement in Northern Austria.

Since 2006, the raw materials of the lithic finds from the Gravettian site of Krems-Wachtberg were systematically analysed under the auspice of the Austrian Academy of Sciences. A sample collection was established, a raw material database was created and every artifact was microscopically analysed (Brandl & Reiter 2008). The investigations primarily aimed at the separation of local and non-local raw materials.

Beyond chronological and spatial dynamics concerning the use of local and non-local resources ("exotic sources"), there are social-anthropological aspects that help understand meaningful differences in human action (compare Chapter 3). The presence of mainly local material demonstrates two important considerations: It is evidence of both, acceptable knapping properties of the available raw material and a reflection of astute choices of prehistoric people. Recognising the presence or absence of raw material from nearby sources can establish conceivable boundaries and the demarcation of territory and influences from certain groups (social, political and ideological). Non-local raw material procurement allows for the reconstruction of probable mobility patterns, contact between groups and related exchange networks (e.g., Kaczanowska 1986; Zimmermann 1995; Kegler-Graiewski & Zimmermann 2003; Zvelebil 2006; Mateiciucová 2010). Recently, the processes linking "settlement dynamics" to lithic resources in the Alpine regions were discussed by Della Casa (2005).

According to first investigations, the majority of the lithics from Krems-Wachtberg can be assigned to local sources. Minor parts of this assemblage represent regional and only a few pieces can be considered far distance imports. As such, it was evident that most raw material groups were local and only a small number of non-local origin, however all high quality radiolarites in the assemblage remained indeterminable.

5.2.2. Radiolarite: Petrography, Palaeontology and Genesis

5.2.2.1. Terminology: Definition of "radiolarite"

Radiolarite is a member of the chert group. A detailed discussion is provided in Section *2.1 Terminology.*

Predominating microfossil inclusions are used in order to define subvarieties of chert such as radiolarite, spiculite or spongiolite. Unfortunately, there is no internationally standardized terminology of these subvarieties. Usually they are defined depending on the percentage of microfossils included in the material, varying between 30% and 70% fossil content of one kind visible under the microscope. One solution for this problem is the suggested definition of chert varieties according to the "index fossil". This is the microfossil obviously dominating the inclusion pattern, independent of the percentage of visible inclusions. According to that terminological system, a radiolarite is a chert of Jurassic age showing radiolarians as the main traits and structural element (Brandl 2010, 185; Cheben & Cheben 2010, 24-26).

5.2.2.2. Petrographical description

Radiolarite can be defined as a quarziferous rock with a micro- (< 20 μm) to cryptcrystalline (< 1 μm) rock structure. It appears in stratified beds or nodular in the shape of concretions. The rock matrix is composed of radiolarian and diatom shells, spicula of calcareous marine sponges, and regularly contains several silicon dioxide minerals and mineral varieties (quartz, moganite, opal, chalcedony). Admixtures of silty, clastic quartz, clay minerals, calcite, muscovite, biotite, rutile and tourmaline are also common in radiolarites (Mišík 1969, 15-126; Cheben & Cheben 2010, 25; Bechter et al. 2010, 24). The SiO_2 content of radiolarite ranges

between 80-90%, but depending on the genesis environment it can show lower values. Especially calcite, as secondary fill of fissures and cavities caused during rock forming processes, is an influencing factor (Cheben & Cheben 2010, 25).

Radiolarian skeletal remains in radolarites occur at various degrees of preservation. Depending on the recrystallisation processes of the rock material during diagenesis, the shells can be perfectly preserved or completely dissolved. In the latter case, these so-called "phantoms" are only detectable under the microscope due to their lack of pigment (Mateiciucová 2008, 48). If preserved, the radiolarian shells are commonly composed of SiO_2-minerals and mineral varieties, or, in the course of pseudomorphosis replacing the silica, of calcite or chlorite (Mateiciucová 2008, 48-49; Cheben & Cheben 2010, 25). Bechter et al. (2010) conducted a Raman-mapping of radiolarians in Eastern Alpine radiolarite (Wien Mauer site). They detected a higher amount of moganite in the radiolarian shell in comparison to the surrounding rock material and the fill of the fossil remains. They hypothesize a slower transformation of the radiolarian shell into α-quartz (which is the final diagenetical state of chert) than the surrounding rock matrix. Cheben & Cheben (2010, 25) analysed the fill of radiolarian skeletons and found two generations of metacolloidal SiO_2, in other cases two generations of chalcedony. Most frequently, the fill consisted of chalcedony and clay minerals, containing a certain amount of calcite. The latter can form the radiolarian shell itself, occur as a monocrystal in the rock matrix or – in rarer cases – absorb the organism and crystallize around the shell. The observation of calcite-rhomboedra filling in the hollow space of the radiolarian skeleton in an initial phase of diagenesis was also made by Pristacz (2008), who analysed samples from the Wien Mauer radiolarite mining site. Subsequently, the calcified radiolarian shells were filled with calcite or SiO_2-spherolites [chalcedony?] were formed.

Radiolarites show a high variation in colour. They range from black over dark-brown, grey-tones, green, blueish, auburn, brick-red, orange and up to yellow. The colouring elements are still under discussion. Red is commonly attributed to Fe-oxides and hydroxides as well as hematite. Darker colours can be caused by Mg-chlorites or the presence of Fe^{3+} clay minerals, carbonates and pyrite. Fe-chlorites are supposed to be responsible for green radiolarite varieties (Cheben & Cheben 2010, 25).

5.2.2.3. Palaeontology

Radiolarians are small microorganisms, typically in a range between 10-100 μm. They are planctonic protozoa, non-motile unicellular organisms with an amorphous silica skeleton exclusively bound to marine environments. The test is the most characteristic morphological feature of radiolarians. The shape of radiolarian tests can vary from spaerical, concentric to conical and show a higher complexity with radiating spines. The largest diversity and number of species occurs in the Equatorial belt region (Ozsvárt 2008, 5). Radiolarians as a taxon show a long range, they occur in the Palaeozoic and last until recent times. In rock-forming quantities, however, they are typical for the Mesozoic period (Elekes et al. 2000, 501-502).

Previous studies have proved that the ratio of radiolarians contained in limestones is unstable, varying between 30 and 90%. In accordance with own investigations, it can be generally stated that almost 70% of the radiolarian remains detected in radiolarites are assigned to Spumellaria, and 30% to Nassellaria. In Jurassic radiolarites, 90% of the matrix is composed of radiolarian skeletons, prevailingly of the Spumellaria type (Polák & Ondrejícková 1993, 410; Cheben & Cheben 2010, 26).

5.2.2.4. Genesis of radiolarite

A detailed discussion concerning the genesis of chert and flint is contained in Chapter 2, Section 2.2. However, for radiolarites a short summary is provided.

As the radiolarians lifecycle ends, their skeletal remains accumulate on the oceans floor. Approximately 1-10% of all marine siliceous debris is deposited. Only very specific environments allow for radiolarian accumulations in rock-forming quantities. Ideal conditions are found in deep-marine facies, where other marine fauna is generally scarce and low water temperature prevents massive accumulation of carbonatic rock material. Such environments exist below the "carbonate compensation depth" (CCD), along submarine volcanic arches in deep sea areas (Elekes et al. 2000, 501-502). During the Jurassic period, the CCD was at about 2000 m below sea level. In comparison, it is nowadays at around 4000-5000 m (Cheben & Cheben 2010, 25). The accumulated radiolarian shells form a stratum of radiolarian silt. Radiolarite formation processes from radiolarian silt happen through diagenesis at a very slow

rate, not producing more then some centimeters rock material per million years (Ekeles et al. 2000, 502).

5.2.3. The Krems-Wachtberg site

5.2.3.1. The setting of the site

The Krems-Wachtberg site is located on a promontory between the watercourses of the Danube and the river Krems **(Fig. 5.2.1.)**. The extension of the site is approximately 200 m^2. The archaeological horizons are buried under 5.5 m loess sediment and slightly slope down to the Danube valley in a south-eastern direction. Evidence for multiple settlement of the area between 33.000 and 27.000 years BP emphasizes the favourable conditions of this locale. Since 2005, excavations at Krems-Wachtberg have revealed exceptional finds, for example two infant burials and a multiphased hearth, all of which are connected with a living floor (AH 4.4) dating to 26.580 +/- 160 years BP showing excellent preservation conditions. All distinct finds belong to the Older Gravettian, in particular to the regional group of the Pavlovian (Einwögerer et al. 2006; Ziehaus 2007; Neugebauer-Maresch 2008; Händel et al. 2009).

The lithics recovered at the Krems-Wachtberg site originate from the archaeological layer AH 4. This stratum is again divided into the sublayers AH 4.11 and AH 4.4. Archaeological horizon AH 4.11 represents a stratum influenced by solifluction processes, AH 4.4 is considered in situ.
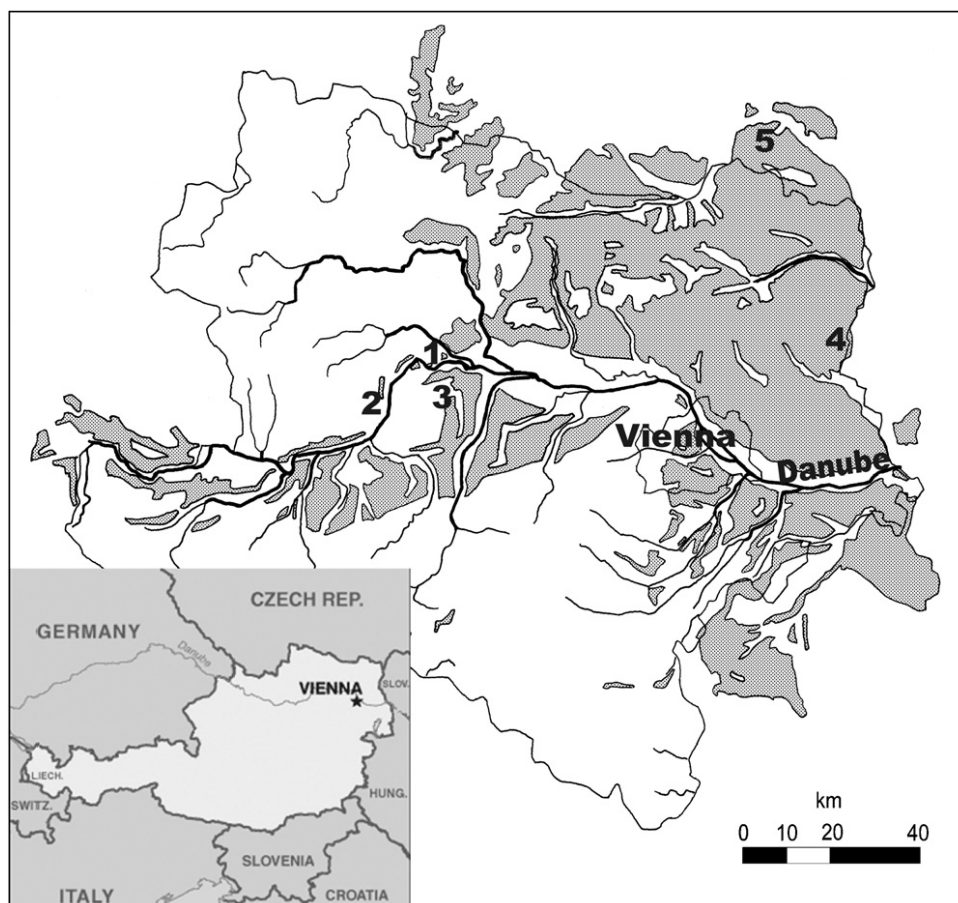
Fig. 5.2.1.: The location of Krems-Wachtberg and other Upper Palaeolithic sites in Lower Austria and the Czech Republic

Loess distribution in Lower Austria is shown by the rasterized area.

Key: (1) Krems-Wachtberg; (2) Willendorf; (3) Paudorf; (4) Stillfried; (5) Pavlov, Dolni Veštonice.

Graph: Prehistoric Commission, Austrian Academy of Sciences (Händel et al. 2009).

5.2.3.2. The lithic finds at Krems-Wachtberg

Until 2008, 11,261 lithic finds were recovered at Krems-Wachtberg. All artifacts were microscopically investigated, however, for preliminary provenance studies only pieces above 9.9 mm were analysed in order to minimize misidentifications (Thomas & Ziehaus 2011, Table 1). An error of approximately 10-15% is generally implied identifying Palaeolithic assemblages.

The majority (N=10,587) of the Krems-Wachtberg lithics are of local provenance, while some (N=369) are unknown **(Table 5.2.1.)**. Combined, these total 10,956 lithics, of which 3,050 show some preservation of their natural surfaces. From the latter group, 937 radiolarites originate from the catchment area of the NCA and 20 high quality artifacts are indeterminable

(Table 5.2.1.). As indicated by artifacts with cortical remains, sources are mainly river gravels containing rocks from the Bohemian Massif, the Flyschzone and the Northern Calcareous Alps. The most important of these local gravel sources is the river Danube located one kilometer from the site. Only 305 artifacts of the assemblage can be clearly assigned to distant source regions. These catchment areas for raw material procurement of the Gravettian people at Krems-Wachtberg are to the north and to the east, in Lower Austria, Moravia, Bohemia and possibly as far as southern Poland.

raw material	provenance	AH 4.4	AH 4.11
chert	NCA	1438	809
chert	Krumlovský les (I) type	2	4
chert	Stranska Skala type	0	2
chert	Vienna Basin type	69	15
chert	Moravian jurassic chert	6	4
chert	indet.	140	24
radiolarite	NCA	1955	1569
radiolarite HQ	**indet.**	**64**	**43**
radiolarite	indet.	64	5
spiculite	NCA	856	410
spongiolite	NCA	97	67
siliceous limestone	NCA	1971	1221
quartzite	Bohemian massif, Flysch Zone	74	117
chalcedony	Northern Lower Austria, "Bunte Serie",	48	30
jasper	Waldviertel	4	7
flint	erratic (Northern Moravia or Soutthern Poland)	55	58
vein quartz	Bohemian massif, Flysch Zone	1	2
rock crystal	Waldviertel (?)	0	1
indeterminable		19	10
TOTAL		**11261**	

Table 5.2.1.: Raw material varieties and provenance at Krems-Wachtberg.

Graph: M. Brandl.

In total, 3,700 lithics from Krems-Wachtberg are radiolarites. Most of them derive without doubt from local river gravel banks, however, 107 show a markedly different appearance. These radiolarite artifacts are highlighted in bold in **Table 5.2.1.** (radiolarite HQ = high quality radiolarite). For the present study, 10 high quality radiolarite artifacts from the Krems-Wachtberg site **(Fig. 5.2.2.)** and samples from 10 comparative radiolarite sources were investigated.

Fig. 5.2.2.: Sampled radiolarite artifacts from Krems-Wachtberg

Photo: M. Brandl.

5.2.4. Analytical Techniques

The MLA combining visual (macroscopic), microscopic, mineralogical and geochemical analysis was applied in order to differentiate between radiolarite sources.

The primary research goal was to find a scientific solution for differentiating between the Northern Alpine and Carpathian radiolarite sources and apply the results to the Krems-Wachtberg finds.

Petrographical-mineralogical analysis

Mineralogical investigations were conducted at the Department of Geosciences at the Universalmuseum Joanneum at Graz by W. Postl. The mineral content was determined

applying X-ray diffractometry (XRD), a technique for analyzing a wide range of crystalline materials. This method allows for the detection of crystalline mineral components in small amounts. The detection limit highly depends on the analysed minerals, typically ranging between 2–3%. A Bruker AXS D8 diffractometer were used for long-term recordings of the radiolarite samples (CuKα-radiation, Si-carrier, 5–70° 2-Theta, Step: 0.02°, Step time: 836.1 s). The objective was (1) the identification of minerals included in the samples (feldspar, clay minerals, etc.) and (2) the proof of moganite as described by Pristacz (2008) and Bechter et al. (2010). 12 selected samples were analysed. For comparison reasons, sample material was taken from the same area of the rocks as the samples for geochemical analysis.

Geochemical analysis

A total of 130 samples were investigated, 10 samples from Krems-Wachtberg and up to 15 samples from each geological source for comparison studies. The results were graphically plotted. Samples displaying higher concentrations for other elements such as Ca or Al were analysed by SEM-EDX-WDX (Jeol JSM 6310, Institute of earth Sciences, University of Graz) to determine the SiO_2-content of this sample. By default, a value of 99 wt.% was used for data reduction in Glitter.

5.2.5. Raw materials from the radiolarite sources

Radiolarite samples from geological deposits with archaeological significance were investigated, indicating that only outcrops established as prehistoric sources were chosen for sampling. As a matter of course I concentrated on sources that are situated within the catchment area of possible raw material procurement activities of Palaeolithic people from the Austrian Wachau region. Only sources showing similarities to the Krems-Wachtberg finds were chosen for comparison studies. Samples from the Hungarian source at Szentgál, for instance, were not included for that reason. The map **(Fig. 5.2.3.)** shows the investigated sources in relation to the Krems-Wachtberg site.
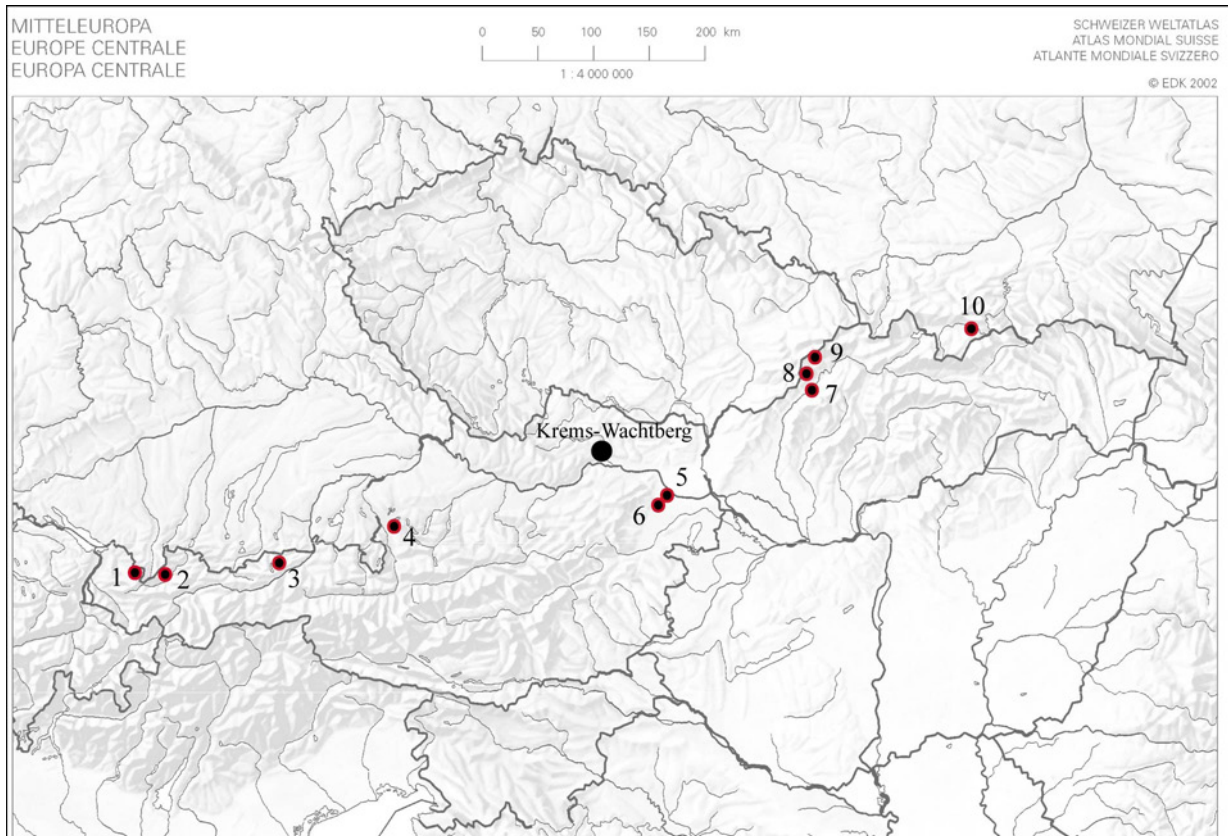
Fig. 5.2.3.: Map of the investigated sources

Key: 1) Feuerstein (FST); 2) Rothornjoch (RH); 3) Grubalacke (GL); 4) Elsbethen/Glasenbachklamm (ELSB); 5) Wien Mauer (WM); 6) Wien Gemeindeberg (WG); 7) Nemšová Kamenice (NEM); 8) Vlára-Bolešov (BOL); 9) Vršatské Podhradie (VRSA); 10) Falsztynski Potok (FAL). *Graph: M. Brandl.*

5.2.5.1. Northern Alpine Sources

Geographical setting

The Northern Calcareous Alps (NCA) form a mountain range within the Eastern Alps north of the Central Eastern Alps located in Austria and the adjacent Bavarian territories of southeastern Germany. They form a mountain belt 500 km in length and 40-50 km wide, ranging from the Rhine Valley and the Bregenzerwald in Vorarlberg (Austria) in the west, extending along the border between Bavaria (G) and Tyrol (A), through Salzburg, Upper Austria, Styria, and Lower Austria, levelling off at the Wienerwald, the city-limits of Vienna, in the east.

Geological setting

The NCA are situated between the crystalline Central Eastern Alps and the Grauwacken Zone in the south and the Flysch and Molasse Zones in the north, overlapping those rock masses partly and forming a typical fold and thrust belt. The rock masses of the NCA are mainly of Permian to Mesozoic depositional age. The radiolarite bearing formations of the NCA are of Upper Jurassic (Malm) origin. At the beginning of the Middle Triasssic, a change from siliciclastic towards carbonatic sedimentation took place (Reichenhaller Wende). This occurance marks the initial stage of the accumulation of shallow water carbonates, which are characteristic for the NCA. Most likely due to the extension of the continental crust, the Tethys proceeded towards the Austroalpine paleogeographic realm during the Pelsonic period. This is when radiolaria occur for the first time in "kalkalpine" (calcareous alpine) sequences, and reefs start to establish.

During the Upper Anisian, the Reiflinger Wende marks the climax of the opening of the Thetys, characterized by chert bearing deep marine limestone formations and tuffites overlying rocks of differing facies formed under shallow water conditions. During the Jurassic, subsidence of the kalkalpine sedimentation area proceeded, accompanied by the accumulation of deep marine carbonates. The climax of the deepening occurs during the Lower Malmian (Ruhpoldinger Wende) and is marked by the occurrence of rocks built up from radiolarian silts (Tollmann 1976; Diersche 1980; Lein 1985).

Samples from the following raw material sources were analysed.

Feuerstein/Kleinwalsertal and Rothornjoch

Both sources are situated in the Allgäu Alps within the Austro (East) Alpine Ruhpolding Formation, comprised of radiolarite series of the Oxfordian. They overlay the series of the Allgäu layers, a marly, Jurassic basin deposit interlocked with Hierlatzkalken, accumulating up to 1580m. The Ruhpolding Formation is again overlayed by Aptychen layers. This basically pertains to the entire western part of the NCA in Vorarlberg and Tyrol. According to Binsteiner (2008), the area at the locale "Feuersteinmähder" (Vorarlberg) is built up by the so-called Bärenkopf-syncline. The Rothornjoch outcrop (Tyrol), only 16 kilometres to the east, shows almost vertically erected radiolarite strata of the Ruhpolding Formation.

From the Feuerstein (FST) source, 10 samples were analysed, and 15 samples from the Rothornjoch (RH) site were investigated.

100

Grubalacke

The Grubalacke (also: Gruberlacke) is located in the Rofan Mountains in Austrian Tyrol. The source is linked to the Ruhpolding Formation as well. A natural depression forms a residual deposit containing deeply weathered radiolarite cropping out close to the surface, along with high amounts of radiolarite secondarily accumulated by glacial processes of a Pleistocene cirque. Eight samples from the Grubalacke (GL) deposit were used for analysis.

Glasenbachklamm/Elsbethen

The Glasenbachklamm is a gorge at the northern edge of the NCA in Salzburg and provides a complete profile of the Lias. In the middle part of the gorge, radiolarite occurs as member of the Oberalm formation, partly overlayed by reddish-yellow calcareous marls. In deeper parts the radiolarite shows a greenish-grey appearance, the upper parts of the deposit are reddish-brown (Bernoulli & Jenkyns 1970). From the primary outcrop (ELSB), 15 samples were taken of the reddish-brown radiolarite layers.

site name	short code	locality	geol. setting/ formation	geol. age	No. of samples	literature
Feuerstein	**FST**	Austria, Vorarlberg, Allgäu Alps	Ruhpolding layers	Upper Jurassic Beckenfacies (Oxfordian)	10	Binsteiner 2008; Leitner 2004; 2006; 2008
Rothornjoch	**RH**	Austria, Tyrol, Allgäu Alps			15	Bachnetzer et al. 2012
Grubalacke	**GL**	Austria, Tyrol, Rofan Mts.			8	Kompatscher & Kompatscher 2005
Elsbethen/ Glasenbach-klamm	**ELSB**	Austria, Salzburg, Osterhorn group	Oberalm layers	Upper Jurassic (Kimmeridgian-Thitonian)	15	Bernoulli & Jenkyns 1970; Rettenbacher 1998

Table 5.2.2.: Sources from the Northern Calcareous Alps (NCA)

Graph: M. Brandl.

5.2.5.2. Sources from the St. Veit Klippen Belt

Geographical setting

The St. Veit Klippen Belt is located at the eastern edge of the Wienerwald, north of the NCA. St. Veit Klippen Belt rock units crop out in the western parts of Vienna and form a range of hills, amongst them Vienna Gemeindeberg, Trazerberg, Girzenberg, Roter Berg and Flohberg (Penz 2007).

Geological setting

At the eastern fringe of the Wienerwald and the northern periphery of the NCA, carbonatic rock masses from the NCA overlap those of the Flysch Zone. Within the Flysch Zone, limestone formations occur along with shaly clays, marls, and sandstones formed during the Upper Jurassic (Thitonian) and the Lower Cretaceous (Neocomian). To some extent, the multicoloured limestones contain deep sea radiolarites, evidence of the subsidence processes on the ocean floor during Middle Jurassic times. These geological formations are characterized as Klippen Zones, as extending elements of the pienidic Klippen of the western Carpathian Mountains (Janoschek et al. 1954; Bechter et al. 2010; Trnka 2011). Rock units of the St. Veit Klippen Belt are tectonically separated from the series of the Grestener Klippen Zone, which is situated within the Hauptklippenzone. According to Prey (1975), the St. Veit Klippen Zone is part of the Kahlenberg Nappe.

Wien Mauer

Mauer, the 23rd district of Vienna, is situated in the southwest of the city. At the easternmost part of the St. Veit Klippen Belt, the Antonshöhe forms one of the monadnocks of this geological zone, reaching an altitude of 356 m above sea level. Prey (1991) assigns the Antonshöhe cliff to a typical St. Veit Klippe. Covering an area of 400 x 120 m, reddish, Upper Jurassic and whitish, Lower Cretaceous limestones are exposed (Bechter et al. 2010; Trnka 2011). They contain radiolarites of various colour and quality, ranging from black over grey, green and brownish to red. Most of the pieces show fissures filled with calcite, however, especially knapping debris from the Neolithic quarry are of better quality. For analysis, 13 of such samples were chosen from Wien Mauer (WM).

Wien Gemeindeberg

The Gemeindeberg is located within the same geological area as the Antonshöhe, in the 13th district of Vienna, Ober St. Veit, only 1.2 km to the southwest of the former. The hill rises to 321 m above sea level. At the Gemeindeberg, the geological stratigraphy shows (from the youngest to the oldest layer): Aptych limestone (Upper Malm – Lower Cretaceous), siliceous limestones with radiolarite (Malm), crinoids limestone (Dogger), marls and marly chalk (Gresten Fornation, Lias-Lower Dogger) and quartz- and arkose-sandstone (Keuper). Archaeological investigations at the slopes of the Gemeindeberg produced evidence for Neolithic settlement as well as radiolarite exploitation activities (Götzinger 2006; Penz 2007).

site name	short code	locality	geol. setting/ formation	geol. age	No. of samples	literature
Wien Mauer	**WM**	Austria, Vienna, 23rd District (Mauer)	St. Veit Klippen Belt (part of the Sulzer Klippen Belt, Flyschzone)	Upper Jurassic (Thiton)- Lower Crateaceous (Neokom)	13	Prey 1991; Bechter et al. 2010; Trnka 2011
Wien Gemeinde-berg	**WG**	Austria, Vienna Hietzing			9	Götzinger 2006; Penz 2007

Table 5.2.3.: Sources from the St. Veit Klippenbelt

Graph: M. Brandl.

5.2.5.3. Carpathian sources

Geographical setting

Sources in the Carpathian Mountains are exclusively bound to the Pieniny Klippen Belt (PKB). The PKB forms the border between the outer and central West Carpathians, a narrow zone stretching at an overall length of approximately 600 km, commencing from the periphery of the Vienna Basin over the White Carpathians up to Poland, where it forms the Pieniny Mountains. From Pieniny, the Klippen Belt passes over to East Slovakia and continues as far as Romania. It is broadest in northwestern Slovakia reaching almost 20 km, and shows the least expanse in eastern Slovakia (Cheben & Cheben 2010).

Geological setting

The Pieniny Klippen Belt is located at the backstop of the Neogene accretionary wedge (External Carpathian Flysch Belt), bordering the Cretaceous nappe stack of the Central Western Carpathians. It comprises of numerous tectonic units, however only few occur throughout the entire Belt. The oldest rock sequences are Middle Jurassic to Upper Cretaceous, the radiolarite formations are of Middle to Upper Jurassic age. Crustal shortening caused extensive overthrusting reflected in the complex setting of the Klippen Belt. The following geological units are described at the PKB: (1) The Czorsztyn Unit, (2) Kysuca (or Kysuce) Unit, (3) Pruske (or Niedzice/Czertezice) Unit, (4) Klape Unit, (5) Orava Unit and (6) Manín Unit. Beyond these, several subunits occur. They are assigned to two types of series within the PKB, nappes of the Oravic Superunit (Czorsztyn unit, Kysuca unit) and frontal elements of the Central Carpathian Fatric Superunit in Western Slovakia (Manín Unit, Drietoma Unit, Klape Unit, Haligovce Unit in the Pieniny Mountains). The Czorsztyn Unit is formed by shallow marine sediments, the Kysuca Unit is of deep marine origin. All other Klippen Belt units, including deep marine rock formations, are situated between these two main units (Plašienka et al. 2012).

According to Birkenmajer (1960; 1977; 1986), several "Klippen Successions" were originally deposited in a united Pieniny Klippen Basin. Within this basin, three main sedimentary domains can be distinguished: (1) The Czorsztyn ridge in the northernmost position of the PKB, (2) the central rift and (3) the southern "Exotic Ridge". During Upper Dogger (Callovian) and Lower Malm (Oxfordian-Kimmeridgian), the Klippen Series geosynclyne reached its maximum depth. All Klippen Belt units with the exception of the Czorsztyn Series contain radiolarite, the deepest facies within the Klippen Series sequence. Radiolarite strata are the most characteristic feature of the Oxfordian and partly of the Callovian/Kimmeridgian stages of the Klippen units. The radiolarite complex of the PKB is associated with nodular, bathyal limestones. The deepening of the marine Klippen basin is best observable in the Pruske (Niedzice) Unit. The stratigraphy shows (from bottom to top): (1) Lower nodular limestone (Bathonian-Callovian), (2) lower red radiolarites (Kamionka radiolarite member, Lower Oxfordian), (3) green radiolarites (Podmajerz radiolarite member, transversarium zone, Middle Oxfordian), (4) upper red radiolarites (Buwald radiolarite member, Upper Oxfordian-Lowest Kimmeridgian) and (5) upper nodular limestone (Kimmeridgian or Kimmeridgian-

Valanginian). This sequence, referred to as Czajakowa Radiolarite Formation, implies that the green radiolarites were formed at the maximum depth of the basin.

Nemšová Kamenice, Vlára-Bolešov and Vršatské Podhradie

All three sites are associated with the Kysuca Unit in the northern part of the White Carpathian Mountains (Biele Karpaty) in the Trenčín Region of Western Slovakia, on the border of the Czech Republic.

At Nemšová Kamenice (NEM, Trenčín county) 12 km northeast of Trenčín in the Vlára river valley, ca. 50 round-oval depressions were interpreted as surface extraction pits. They are irregularly distributed on moderate slopes south and west below the flat hilltop of a Pienidic Klippe. Until today, no archaeological excavation was carried out at this locale (Cheben & Kaminská 2002; Cheben & Cheben 2010).

Vlára-Bolešov (BOL, Ilava county), is located in the Kobylináč range, about 16 kilometres north-northeast of Trenčín in the district of Považská Bystrica and only 4.7 km north of the Nemšová Kamenice site. Between Bolešov and Krivoklát, at Tri kopce, a mining pit was discovered on the southeastern slope (locality Králov vrch) of an exposed Klippe. There, too, archaeological investigations are still to be conducted (Cheben et al.1995; Cheben & Illášová 1997; Cheben & Cheben 2010).

Vršatské Podhradie (VRSA, Ilava county), is situated 21 km northeast of Trenčín and 5.5 kilometers northeast of Vlára-Bolešov in an area characterised by pronounced Klippen. The sampled site is located west of the Chemľová hill on a wooded limestone range running north-south, with a 30 m wide plateau area and steep slopes. At the southwest and at the northeast fringes of this hill range, two radiolarite mining pits situated on an steep ascending slope immediately adjacent to an exposed limestone klippe were detected by Cheben & Cheben (2010) and named „Horná Lysá-baná" (= mine at the upper meadow). An excavation was conducted in 2008 and proved evidence for mining activity. The dating is still under discussion.

Falsztynski Potok

Falsztynski Potok (FAL, Novy Targ county), the easternmost source investigated, is a south tributary to the Czorsztynskie reservoir passing by the small village of Falsztyn in Southern Poland, close to the Slovak border. The sampled site is situated in a bay area on the southern

shore of the Czorsztyn Lake, where radiolarite from nearby Buwałd klippen of the Czajakowa
Radiolarite Formation (Nedzica Series) is secondarily accumulated (Kwiatkowski 1981).

site name	short code	locality	geol. setting/ formation	geol. age	No. of samples	literature
Nemšová Kamenice	**NEM**	Slovakia, okr. Trenčín, kraj Trenčín, White Carpathians	Kysuca Unit, Pieniny Klippen Belt (PKB)	Middle-Upper Jurassic, Dogger-Malm, Callovian-Kimmeridgian	15	Cheben & Kaminská 2002; Cheben & Cheben 2010
Vlára-Bolešov	**BOL**	Slovakia, Bolešov-Tri kopce, okr. Ilava, kraj Trenčín, White Carpathians			10	Cheben et al.1995; Cheben & Illášová 1997; Cheben & Cheben 2010
Vršatské Podhradie	**VRSA**	Slovakia, okr. Ilava, White Carpathians			15	Cheben & Cheben (2010)
Falsztynski Potok	**FAL**	Poland, pow. Novy Targ, Falsztyn, Carpathian mountains	Nedzica Unit (Czajakowa Radiolarite Formation), Pieniny Klippen Belt (PKB)		10	Kwiatkowski 1981; Drobniewicz et al. 1997

Table 5.2.4.: Sources from the Carpathian Mountains

Graph: M. Brandl.

5.2.6. Radiolarites from Krems-Wachtberg

5.2.6.1 Sample description

For the present study, 10 high quality radiolarite artifacts from the Krems-Wachtberg site
were investigated.

Macroscopical description

Macroscopically, all analysed artifacts from Krems-Wachtberg show a reddish-brown colour
range **(Tab. 5.2.5.)**. They are characterized by a cryptocrystalline texture, high homogeneity,
and the absence of typical alpine fissures, thus providing excellent knapping properties.

Microscopical description

All samples from Krems-Wachtberg show similar inclusion patterns. In addition to marine detritus, radiolarians (mainly Spumellaria) and – much scarcer – monaxon spicula are the predominant microfossil inclusions **(Tab. 5.2.5.)**. Most of the microfossils bear the colour of the rock matrix. Irregularly interspersed radiolarians show a bluish appearance from chalcedony or moganite fill.

Find No.	Short Code	munsell colour	fossil inclusions	radiolarian size	
				max µm	min µm
WA 7724	N	10R 3/4 dark reddish brown	radiolarians (ca. 70% content), monaxon spicula, marine sponges tissue, unidentifiable detritus	230	35
WA 7770	O	10R 3/4 dark reddish brown	radiolarians (50–70% content), monaxon spicula, marine sponges tissue, unidentifiable detritus	260	30
WA 7782	P	10R 3/4 dark reddish brown	radiolarians (50–70% content), spicula, marine sponges tissue, unidentifiable detritus	270	35
WA 8183	Q	10R 3/4 dark reddish brown	radiolarians (-70% content), spicula, in parts massively marine sponges tissue and unidentifiable detritus	270	35
WA 8640_31	R	10R 3/4 dark reddish brown	radiolarians (-50% content), scarcley monaxon spicula and marine detritus	270	35
WA 15354	S	10R 3/4 dark reddish brown - 5YR 4/4 moderate brown	radiolarians (-70% content), more abundantly monaxon spicula and marine detritus	260	35
WA 17913	T	10R 3/4 dark reddish brown	radiolarians (50–70% content), monaxon spicula, marine detritus	230	30
WA 68497	U	10R 3/4 dark reddish brown	radiolarians (50–70% content), spicula, in parts massively marine sponges tissue and unidentifiable detritus	270	35
WA 74327_29	V	5YR 3/2 grayish brown - 5R 2/2 blackish red	radiolarians (50–70% content), monaxon spicula, marine detritus	270	35
WA 87982_46	W	5YR 3/2 grayish brown - 5R 2/2 blackish red	radiolarians (80% content), scarcely spicula and unidentifiable marine detritus	270	35

Table 5.2.5.: Description of the sampled radiolarite artifacts from Krems-Wachtberg

Graph: M. Brandl.

5.2.6.2. Surface alteration of lithic artifacts at Krems-Wachtberg

At Krems-Wachtberg, I only detected heavy patination effects on lithic artifacts that were subjected to heat (fire influence). The majority of the lithic finds only exhibit light surface alteration in terms of colour change (probably bleaching) and in and some cases a coarsening of the surface. These effects can mainly be ascribed to the alternating action of moisture and dehydration of the soil. Additionally, the pH-value of the Krems-Wachtberg loess is approximately 7.2, which corresponds to a slightly alkaline environment (*personal communication Robert Peticzka*). Considering the time span of deposition, this certainly had influence on the rock surfaces of the lithic finds confirming these observations.
For LA-ICP-MS investigation, it was ensured that only samples unaffected by patination were analysed.

5.2.7. Results

5.2.7.1. Macroscopical investigations of the radiolarite sources (MLAS 1)

In general, Carpathian raw materials show a finer granularity in combination with a brighter colour and appear to be less fractured by rock formation processes than the Northern Alpine samples **(Tab. 5.2.6.)**. The latter bear typical alpine fissures, one of the most characteristic properties of cherts from the NCA. Nevertheless, high quality pieces can be found in northern alpine sources as well and Carpathian radiolarites can be heavily fractured. Therefore, such visual attributes do not afford a clear distinction between the two source regions.

context	source	munsell colour of the investigated samples	visual characteristics
Northern Calcareous Alps	FST	5R 3/4 (dusky red) - 5R 2/6 (very dark red) - 10R 3/4 (dark reddish brown); 5G 7/2 (pale green) - 5G 5/2 (grayish green) -10G 6/2 (pale green) - 5B 6/2 (pale blue) - 5YR 4/1 (brownish gray)	partly heavily cleft, shiny gloss on fractured surface, typical colour range
	RH	5YR 3/2 (grayish brown) - 10R 3/4 (dark reddish brown); 5G 5/2 (grayish green) - 5BG 5/2 (grayish blue green)	partly heavily cleft, shiny gloss on fractured surface
	GL	10R 6/6 (moderate reddish orange) - 10R 4/6 (moderate reddish brown)	sometimes cleft, characteristic color range
	ELSB	5R 3/4 (dusky red) - 10R 3/4 (dark reddish brown) - 10R 4/6 (moderate reddish brown)	partly heavily cleft, shiny gloss on fractured surface
St. Veit Klippen Belt	WM	10R 4/2 (grayish red) - 10 R 4/6 (moderate reddish brown) - 10R 3/4 (dark reddish brown); 5YR 6/1 (light brownish gray) - 5Y 6/1 (light olive gray) - 5GY 6/1 (greenish gray) - 5G 6/1 (greenish gray) - 5B 5/1 (medium bluish gray)	highly variable in colour, often heavily cleft, radiolarian phantoms
	WG	5GY 6/1 (greenish gray) - 5G 6/1 (greenish gray) - rarer 5B 5/1 (medium bluish gray), fractions of 5R 4/6 (moderate red) and 10Y 7/4 (moderate greenish yellow)	sometimes cleft, rhomboedric cavities (calcite inclusions)
Carpathian Mountains	NEM	10R 6/6 (moderate reddish orange) - 10R 4/6 (moderate reddish brown); 5GY 6/1 (greenish gray) - 5G 6/1 (greenish gray)	sometimes cleft, glossy on the fractured surface
	BOL	5R 3/4 (dusky red) - 10R 3/4 (dark reddish brown)	very dense, sometimes fissured, glossy on the fractured surface
	VRSA	10R 5/4 (pale reddish brown) - 10R 4/2 (grayish red) - 10R 4/6 (moderate reddish brown) - 10R 3/4 (dark reddish brown)	very dense, sometimes heavily cleft, glossy on the fractured surface
	FAL	5R 4/6 (moderate red) - 5R 4/3 (dusky red) - 5YR 3/2 (grayish brown); fractions of 5BG 7/2 (pale blue green) - 5B 8/2 (very pale blue)	very dense, glossy on the fractured surface

Table 5.2.6.: Visual properties of the comparative samples

Graph: M. Brandl.

5.2.7.2. Microscopical investigations of the radiolarite sources (MLAS 2)

Most of the northern alpine samples show comparable inclusions to the Carpathian material **(Fig. 5.2.4.)**. All samples show radiolarian inclusions (mainly Spumellaria) which bear a bluish colour either deriving from chalcedony or moganite fill (Diersche1980, 88-92; Bechter et al. 2010, 31-33).
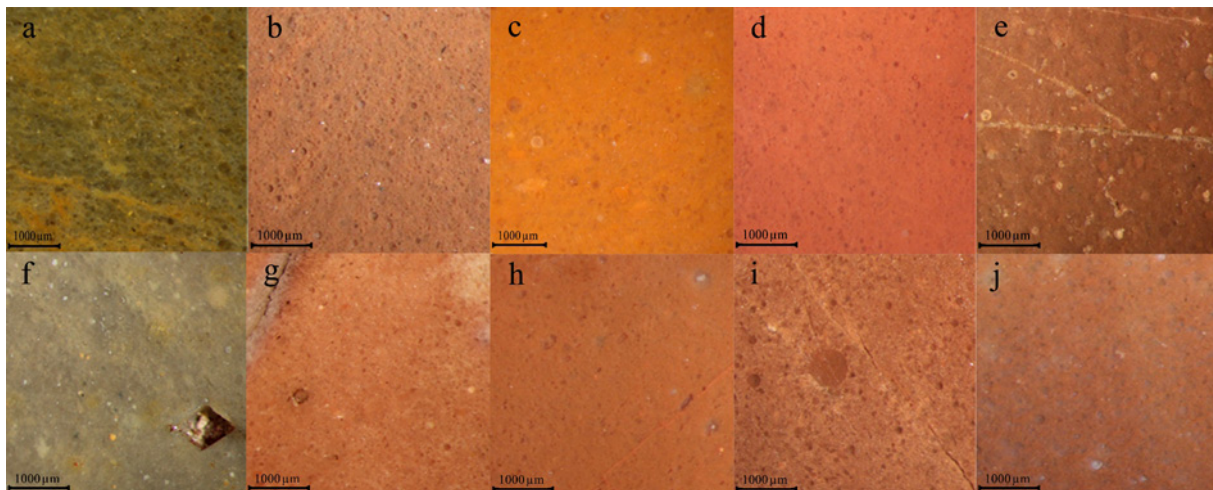
Fig. 5.2.4.: Micropictures of the comparative raw material samples

Key: a) FST; b) RH; c) GL; d) ELSB; e) WM; f) WG; g) NEM; h) BOL; i) VRSA; j) FAL.

Photos: M. Brandl.

As illustrated in **Table 5.2.7.**, some radiolarians in the Carpathian samples are larger (40–660 µm) than in the comparative northern alpine samples (30–430 µm) as well as in specimens from the St. Veit Klippen Belt sources (30–300 µm). Samples from the latter show markedly different inclusion patterns, Wien Mauer bears radiolarian "phantoms" from weathered calcite fill of the radiolarian shells and Wien Gemeindeberg retained trigonal crystal cavities, originating from carbonate inclusions in the rock matrix, most likely calcite (Pristacz 2008, 26-33; 35-39). These properties appear to be characteristic for the occurrences and contain the possibility for a distinction.

Spicula inclusions provide an additional possibility for a differentiation. Unfortunately, compared to radiolarian remains, spicula are much scarcer in the fossil content of radiolarites. Previous investigations (Brandl & Reiter 2008, 46) revealed almost exclusively monaxon spicula in NCA cherts, whereas chert and flint samples from outside the northern alpine range contained both monaxon and multi-radial spicules. However, only a few radiolarite samples investigated for this case study showed significant spicula inclusions suitable for such a distinction.

context	source	fossil inclusions	radiolarian sizes		Texture
			max µm	min µm	
Northern Calcareous Alps	FST	radiolarians (-70% content, often much lower and poorly preserved), monaxon spicula, marine detritus	300	30	crypto-crystalline
	RH	radiolarians (-70% content, in some cases more), monaxon spicula, marine detritus	430	35	crypto-crystalline
	GL	radiolarians (-80% content), monaxon spicula, marine detritus	350	40	micro-/ crypto-crystalline
	ELSB	radiolarians (-70% content), monaxon spicula, marine detritus	300	40	micro-/ crypto-crystalline
St. Veit Klippen Belt	WM	radiolarians (50–70% content, many phantoms), monaxon spicula, marine detritus	300	40	micro-/ crypto-crystalline
	WG	radiolarians (-50% content), monaxon spicula, marine detritus	170	30	crypto-crystalline
Carpathian Mountains	VRSA	radiolarians (-70% content), monaxon and multi-radial spicula, sponges tissue, unidentifiable marine detritus	660	70	crypto-crystalline
	BOL	radiolarians (50–70% content), scarcer spicula (monaxon and multi-radial), sponges tissue, unidentifiable marine detritus, very rarely sea urchins needles	350	65	
	NEM	radiolarians (-80% content), scarcer multi-radial spicula, marine detritus	300	40	
	FAL	radiolarians (50–70% content, often diagenetically deformed), scarcer spicula (monaxon and multi-radial), sponges tissue, unidentifiable marine detritus	400	90	

Table 5.2.7.: Microscopical properties of the comparative samples

Graph: M. Brandl.

5.2.7.3. Mineralogical-Petrographical analysis (MLAS 3)

XRD analysis was conducted in order to identify the mineral phases present in selected radiolarite samples. The investigations revealed only limited results **(Table 5.2.8.)**. In most cases, only quartz was detected, as well as, hematite as a colouring mineral component for the RH and FAL sources. Low reflections assigned to potassium feldspar/plagioclase in the BOL and RH samples could not be reproduced. Due to method-inherent restrictions, tridymite and

moganite contents as described by Pristacz (2008) and Bechter et al. (2010) are below the detection limit if not mentioned at **Table 5.2.8.**

site	sample No.	colour	RöNo.	XRD results
RH	133	olive-green	35281	quartz +/- minimal peak at d = 3.21 Å (potassium feldspar? plagioclase?) at detection limit (d.l.)
RH	135	red	35282	quartz +/- hematite (at d.l.); +/- moganite at d.l.
FST	32	red	35283	quartz
NEM	101	green	35284	quartz
NEM	111	pale green	35285	quartz
WG	27	green	35291	quartz
BOL	15	red	35292	quartz +/- very small peak at d = 3.24 Å und d = 3.19 Å (potassium feldspar + plagioclase?)
FAL	4	red-green	35293	quartz +/- hematite (at d.l.)
VRSA	126	reddish	35294	quartz +/- moganite at d.l.; +/- calcite at d.l.
ELSB	152	red	35295	quartz +/- moganite at d.l.; +/- calcite at d.l.
GL	-	red	35296	quartz +/- moganite at d.l.
WM	-	red	35297	quartz +/- moganite at d.l.;. +/- minimal peak at d = 3.23 Å (potassium feldspar?)
		green	35298	quartz +/- calcite
RH	133	olive-green	35304	Analytical check of RÖ 35281: Quartz +/- calcite at d.l.;. +/- minimal peak at d = 2.70 Å; minimal peak at d = 3.21 Å not reproducible!
BOL	15	red	35305	Analytical check of RÖ 35292: Quartz +/- minimal peak at d = 2.706 Å (hematite? at d.l.); group of minimal peaks between d = 3.24 and 3.19 Å not reproducible.

Table 5.2.8.: Results of XRD–analysis

Graph: M. Brandl.

5.2.7.4. Geochemical analysis

According to previous investigations, cations showing colouring permutation on SiO_2-rocks were found to be unsuitable for a source distinction. Fe, Mn, Ni and similar elements are enriched in intensely coloured areas and less concentrated in lighter rock parts, independent of the origin of the radiolarite samples **(Fig. 5.2.5.)**. High field strength elements such as Al and Ti are usually immobile and allow a vague distinction between sources. The Al versus Ti

concentration plot shows a basic 45° trend in **Fig. 5.2.6.**, indicating that these elements may replace Si-cations. Elements Li and B allowed for a clear distinction between lacustrine and marine cherts (Postl et al. 2008a and b; Brandl et al. 2011), however, they are not usable for the present research question since the depositional environment is marine for all samples **(Fig. 5.2.7.).**
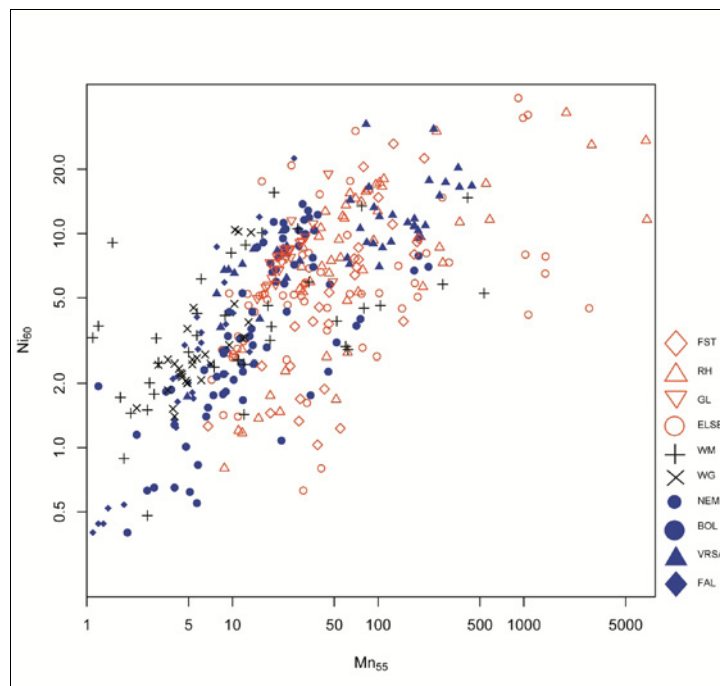
**Fig. 5.2.5.: Manganese versus nickel concentration plot
of the radiolarite sources**
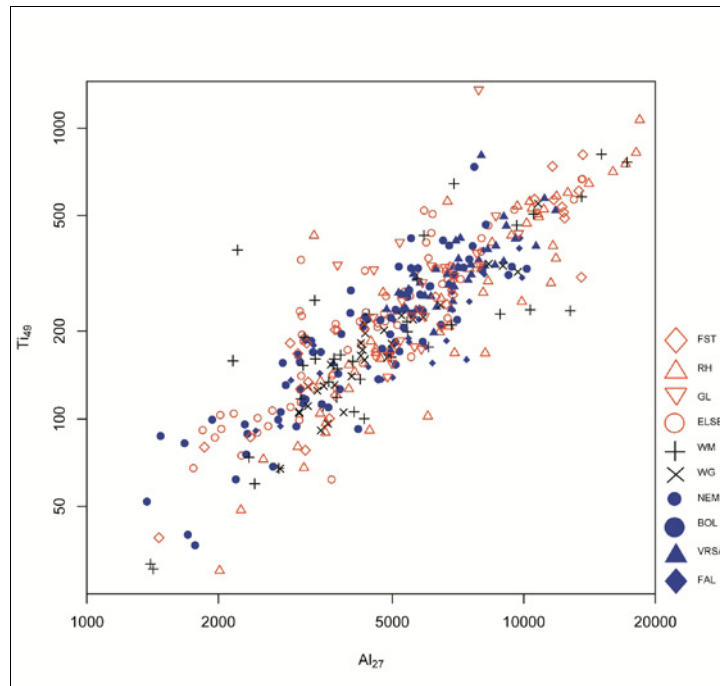
Fig. 5.2.6.: Aluminium versus titanium concentration plot of the radiolarite sources
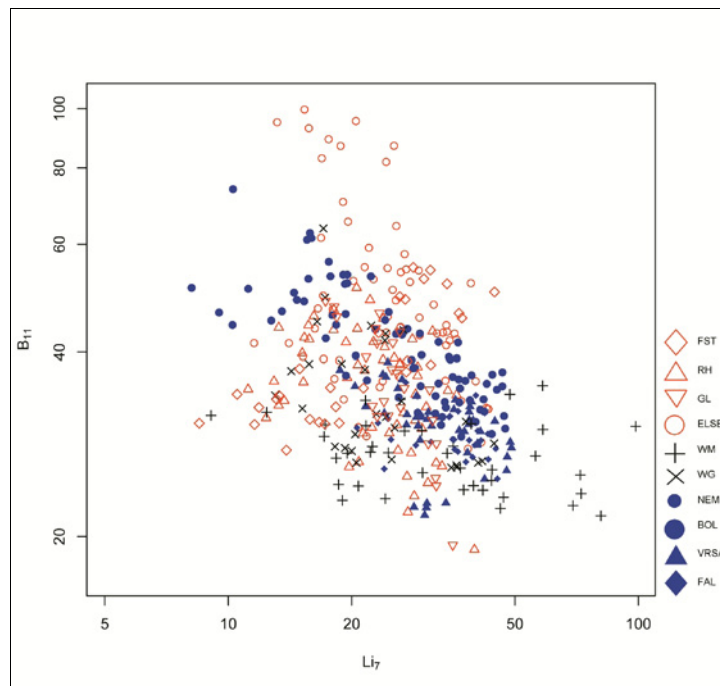
Fig. 5.2.7.: Lithium versus boron concentration plot of the radiolarite sources

Cations like Ba, Mg, Sr, V and Rb are enriched in inclusion minerals like feldspars and carbonates, but can also be deposited in pore spaces. In combination with the trace elements

Al, Ti, Cu and Zn, samples from the Northern Calcareous Alps and the Carpathian Mountains demonstrate different trends, allowing for a distinction between raw material clusters from the NCA and the Carpathians.

This is best seen in the Ba–Mg concentration plot **(Fig. 5.2.8.)**. However, some overlapping of several data points does occur. A few data points of the FAL source are interspersed into the RH and FST data cluster, easternmost and westernmost radiolarite deposits. They can be distinguished by the geochemical data as can be seen by the Ca versus Al and Ca versus Mg plots **(Fig. 5.2.11.)**. Some data points from BOL and VRSA overlap with the RH cluster as well. The chemical similarity can be attributed to similar genetic formation processes in deep water sediments during Upper to Middle Jurassic times. Values from NEM are clearly different from those of all NCA samples as displayed in the Ba–Mg plot **(Fig. 5.2.8.)**.

The WM source on the other hand shows overlapping to a greater extent, especially the samples containing comparatively low values of Ba and Mg. They scatter throughout the data clusters of the NCA as well as the Carpathians. Considering the geological location of WM, which is situated between the NCA and the Klippen Belt, the geochemical results can be interpreted as a reflection of the physiographic setting of the radiolarite source. Located in the same geological area, however, the WG source shows closer geochemical affiliation to the NCA.
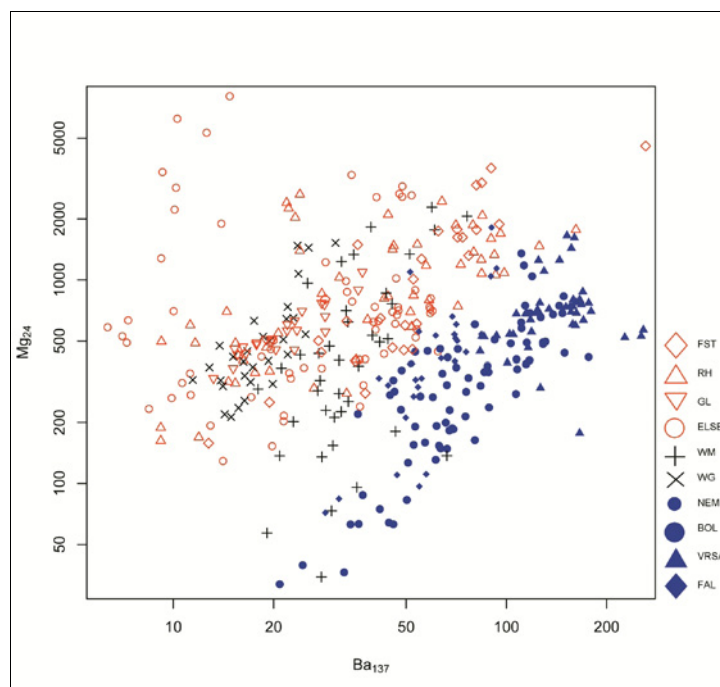
Fig. 5.2.8.: Barium versus magnesium concentration plot
of the radiolarite sources

However, Ba and Mg contents cannot be used for a differentiation between specific sources within the main raw material clusters, namely NCA versus Carpathians. A better differentiation is provided by Ba versus Sr for NEM, GL and to some degree for VRSA and FST **(Fig. 5.2.9.).** Strontium versus vanadium **(Fig. 5.2.10.)** and to a lesser extent rubidium affords the definition of independent clusters of the GL source and to a certain degree of the NEM deposit.
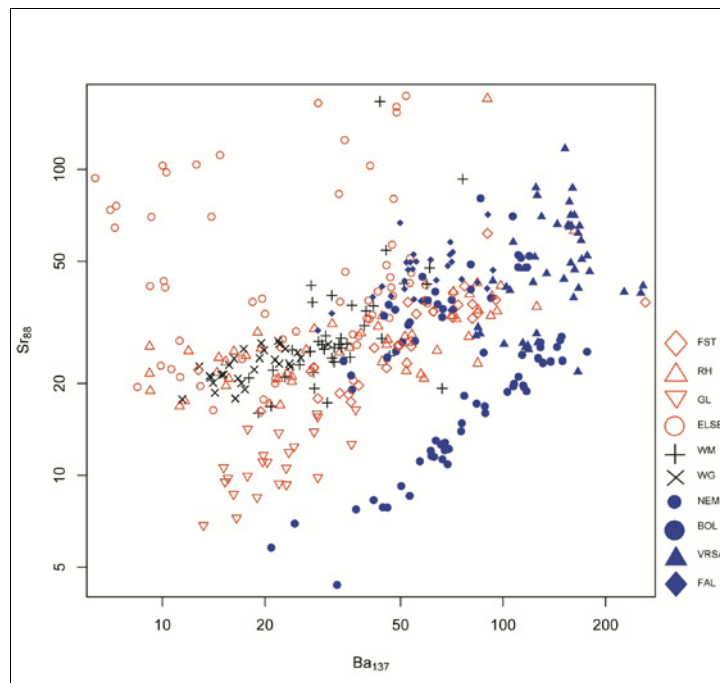
**Fig. 5.2.9.: Barium versus strontium concentration plot
of the radiolarite sources**
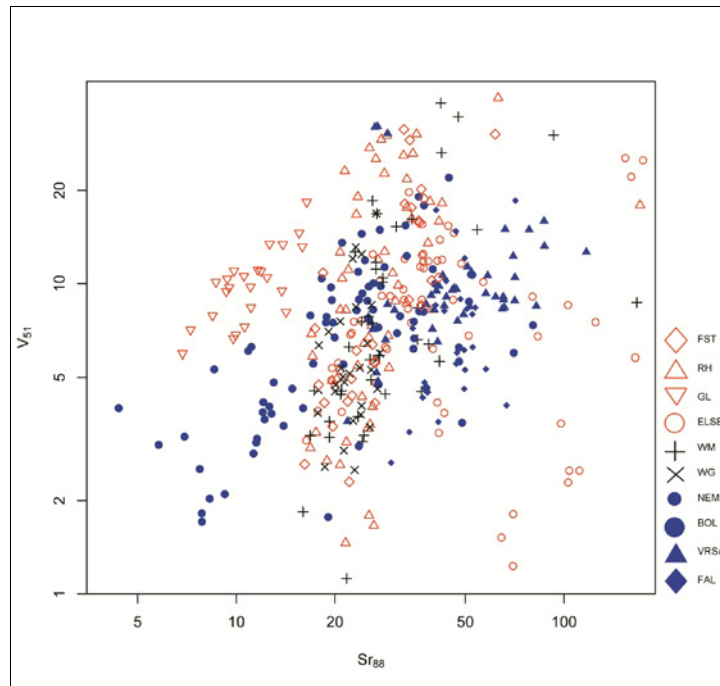
**Fig. 5.2.10.: Strontium versus vanadium concentration plot
of the radiolarite sources**

Correlations with Ca (calcium)

In order to evaluate the origin of trace elements, several elements were plotted against Ca. The element Ca usually occurs in mineral inclusions in radiolarite as calcite, dolomite, or plagioclase and clay minerals. Thus, Ca correlation plots were used to see systematic trends which are related to the inclusion minerals.

The majority of ELSB and VRSA samples exhibit relatively high contents of Ca; ELSB samples also display relatively high values of Mg **(Fig. 5.2.11. a + b)**. Deposits at ELSB, WG, FST and GL in the NCA and NEM, BOL and FAL in the Carpathians show values indicating plagioclase and/or clay minerals (Ca–Al).

These results are correlated to source specific genetic conditions of the analysed samples. The Ca versus Al concentration plot shows values assigned to the presence of Ca-rich plagioclase ($CaAl_2Si_2O_8$) of the FST, RH, WG, BOL and FAL sources (Ca:Al in a 1:2 ratio). NEM, VRSA, ELSB, WM and GL show insignificant values of Ca. The same trend occurs in the Ca versus Mg-plot. Additionally, a correlation between Ca and Sr, which behaves geochemically similar to Ca, is present for GL and VRSA. Due to the very low concentrations of mineral inclusions in the majority of the radiolarite samples, XRD analysis did not produce clarifying results concerning plagioclase and/or clay minerals.
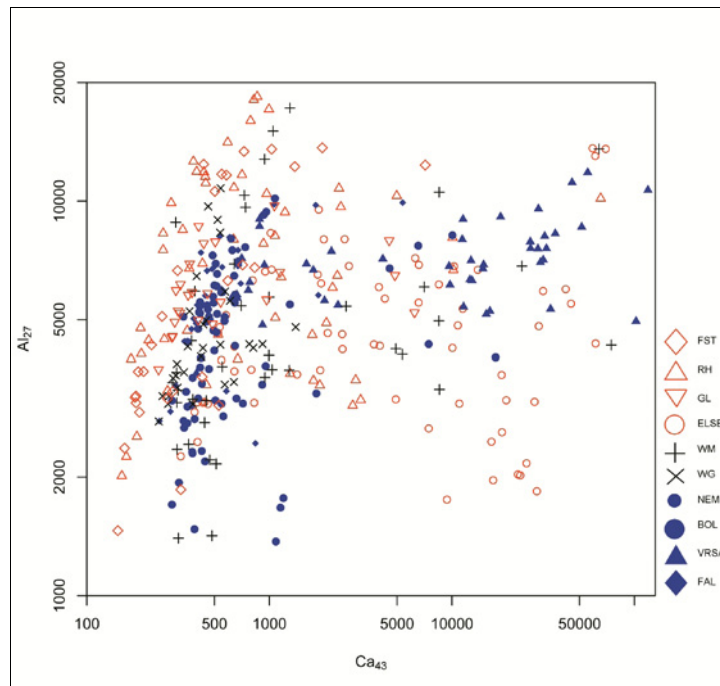
Fig. 5.2.11. a: Calcium versus aluminium concentration plot of the radiolarite sources
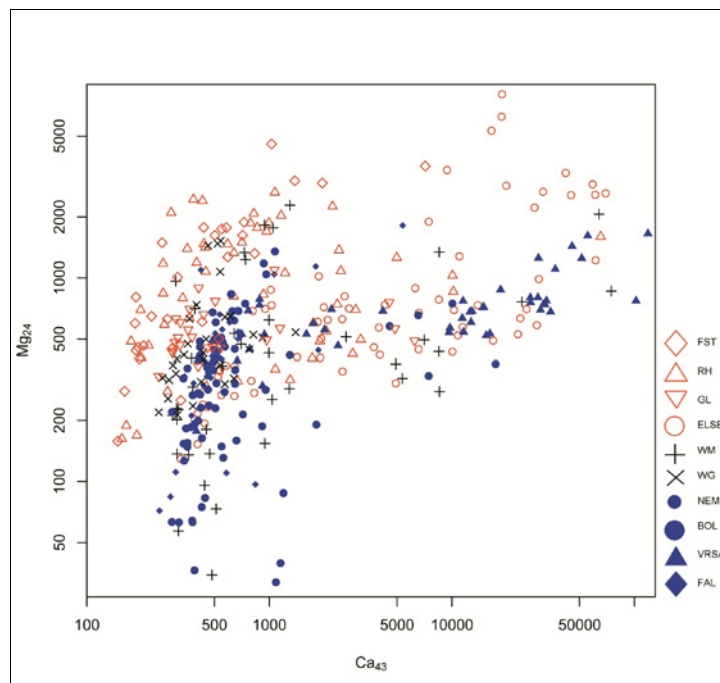
**Fig. 5.2.11. b: Calcium versus magnesium concentration plots of the radiolarite sources**

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5.2.7.5. Application to the finds from Krems-Wachtberg – macroscopical, microscopical and geochemical results

Macroscopical comparison did not reveal suitable results for a correlation and assignment of the Krems-Wachtberg finds to the investigated source regions. Similarities between the archaeological finds and most of the geological samples are too close to make a distinction. Samples from WM and WG as well as the GL source can be excluded with a high certainty due to the characteristic properties described above.

Microscopically, the possibilities for a distinction between sources from the NCA and the Carpathians are also very limited, and do not afford comparisons with the archaeological samples. The sizes of the radiolarians included in the artifacts are very consistent as displayed in **Tab. 5.2.5.** and **Fig. 5.2.12.**, additional fossil inclusions occur randomly and are not representative of either source.
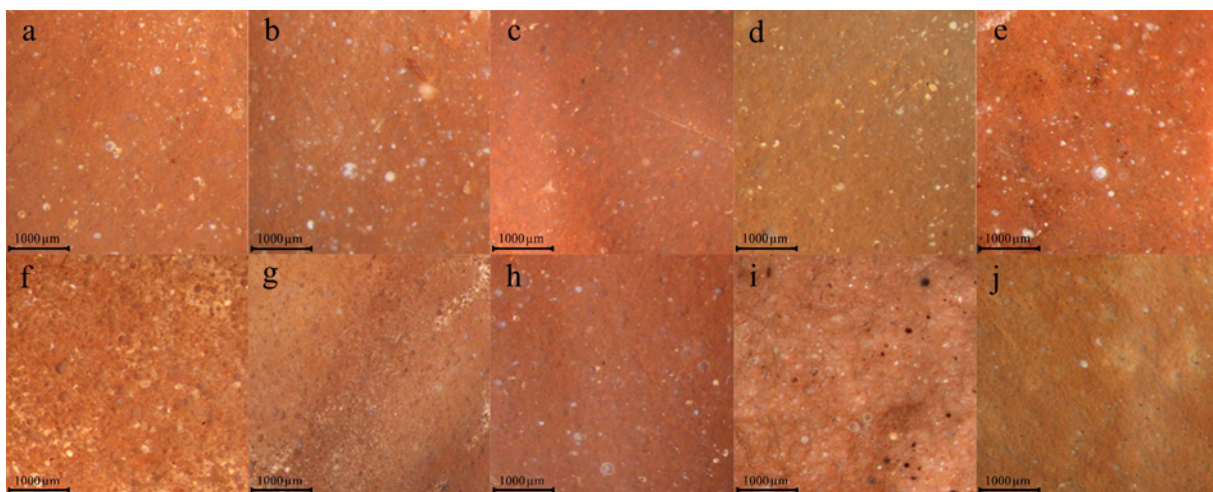
Fig. 5.2.12.: Micropictures of the Krems-Wachtberg artifacts

Key: a) WA 7724; b) WA 7770; c) WA 7782; d) WA 8183; e) WA 8640/31; f) WA 15354; g) WA 17913; h) WA 68497; i) WA 74327/29; j) WA 87982/46. *Photos: M. Brandl.*

As demonstrated in previous studies, a geochemical approach is exceedingly promising for assigning prehistoric stone tools to source regions (Postl et al. 2008a and b; Brandl et al. 2011). Ten high quality radiolarites from Krems-Wachtberg were sampled and analysed applying LA-ICP-MS **(Fig. 5.2.2.)**. Eight of the sampled artifacts were chosen from the archaeological horizon AH 4.4, and two from AH 4.11.

Geochemical parameters Ba in combination with Mg, Sr, Ti and Cr can be used for differentiating between samples from the NCA and the Carpathian Mountains. When applied to the Krems-Wachtberg radiolarites, the Ba–Mg concentration plot shows that all samples except for one are situated in the northern alpine cluster **(Fig. 5.2.13.)**. This is supported by trace elements Sr, Cr, Cs, and Ti, as well as, by the Al concentrations detected in the samples **(Fig. 5.2.14.)**.
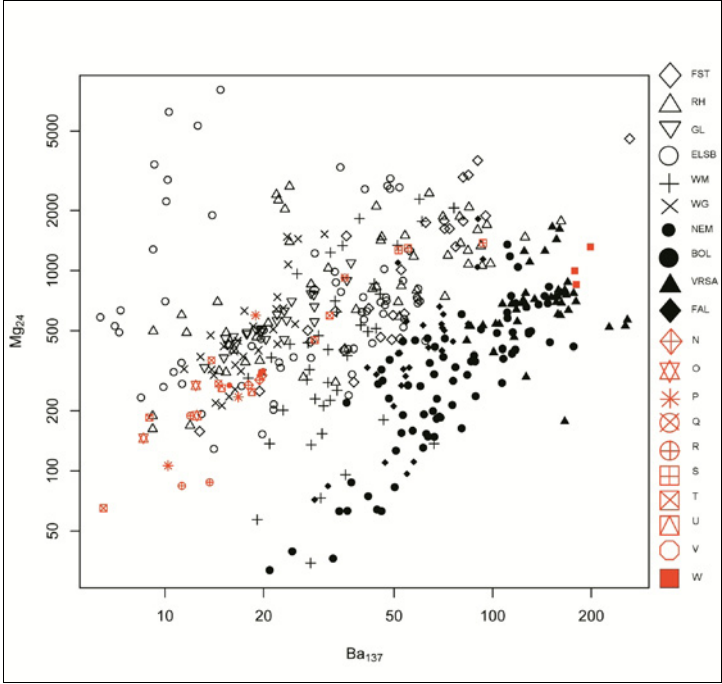
**Fig. 5.2.13.: Barium versus magnesium concentration plot
of the radiolarite sources and the Krems-Wachtberg samples**
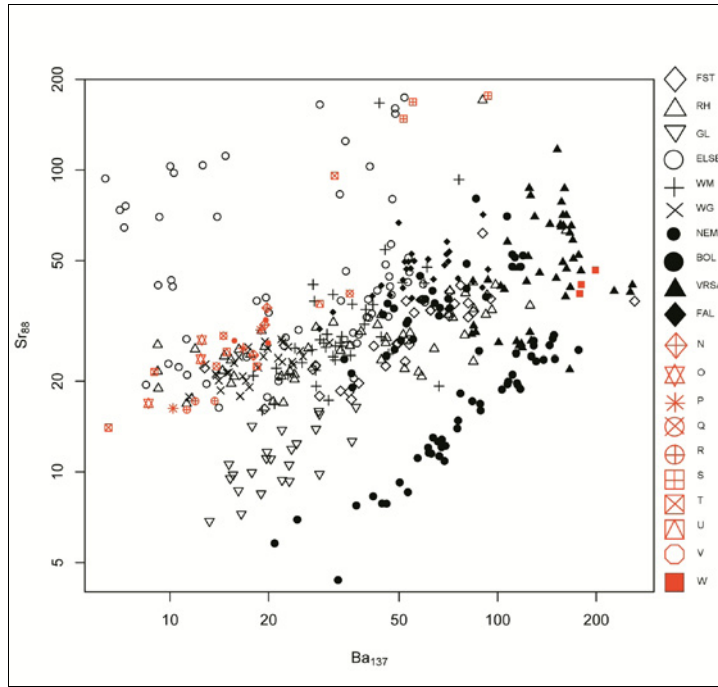
Fig. 5.2.14. a: Barium versus strontium concentration plot of the radiolarite sources and the Krems-Wachtberg samples
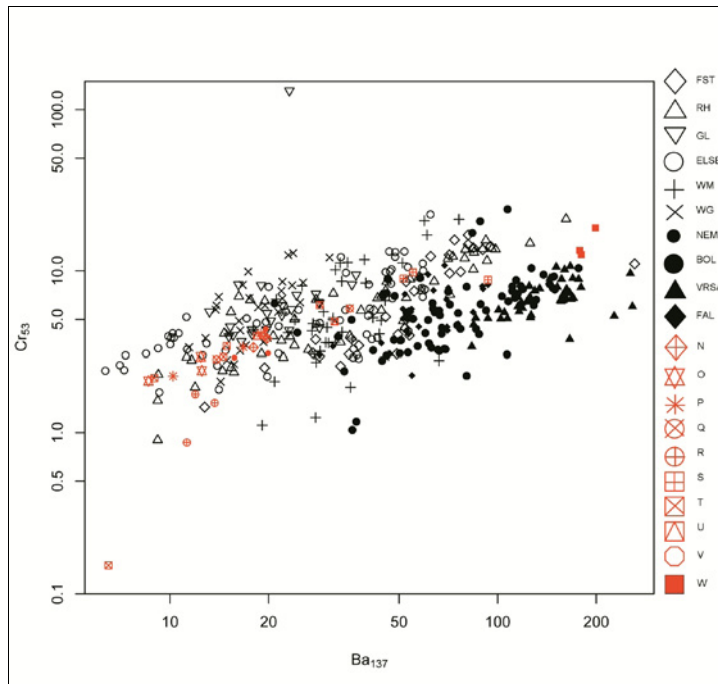
Fig. 5.2.14. b: Barium versus chromium concentration plot of the radiolarite sources and the Krems-Wachtberg samples
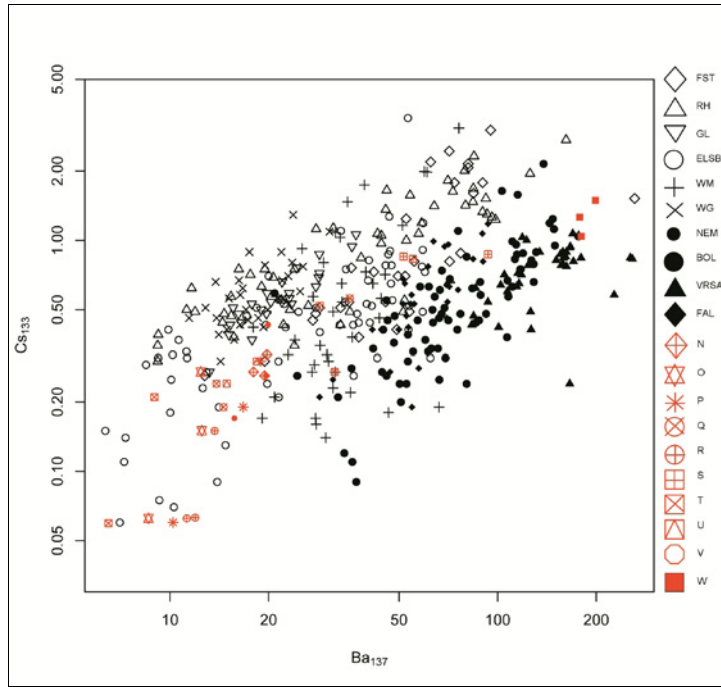
Fig. 5.2.14. c: Barium versus caesium concentration plot of the radiolarite sources and the Krems-Wachtberg samples
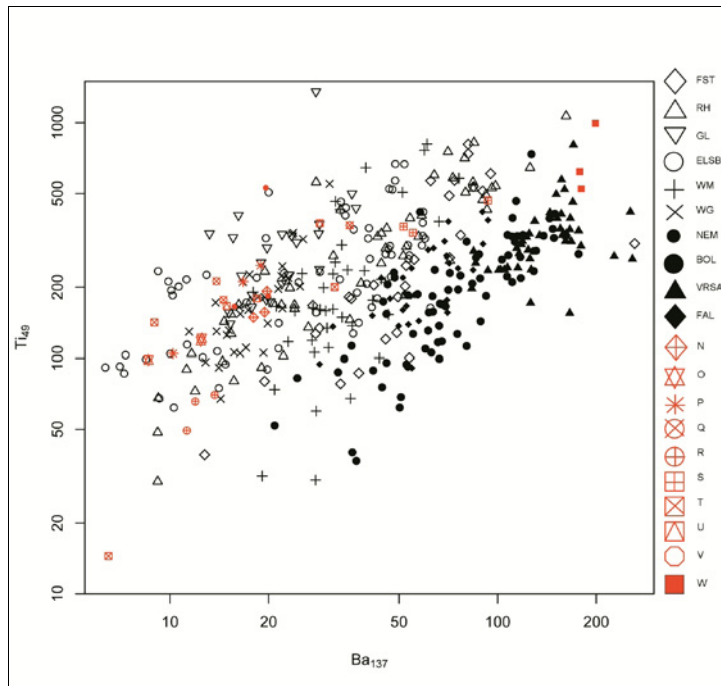
Fig. 5.2.14. d: Barium versus titanium concentration plot of the radiolarite sources and the Krems-Wachtberg samples
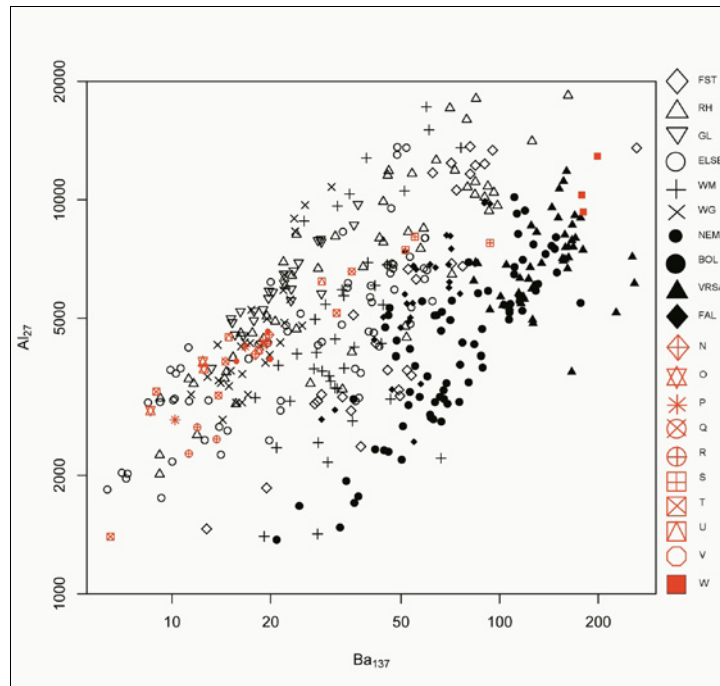
Fig. 5.2.14. e: Barium versus aluminium concentration plot of the radiolarite sources and the Krems-Wachtberg samples

5.2.8. Discussion

Investigations concerning chemical distinction of radiolarites in an archaeological context in Central Europe are a recent endeavor. It was mainly a consequence of geological surveys and the examination of "flint mining" sites that researchers became concerned with this raw material variety (Elekes et al. 2000). For the regions discussed in the present paper, it is obvious that in the Czech Republic (Skutil 1953; Vencl 1970; Oliva 1991; Pavelčík 1993; Verpoorte 1997; Přichystal 1994a; 2004; 2009; Škrdla 2005; Oliva 2012), Hungary (Biró & Regenye 1991; Bacskay 1995; Biró 1995; Biró et al. 2000; Elekes et al. 2000; Biró & Regenye 2003), Slovakia (Skutil 1947; Skutil 1964; Cheben et al. 1995; Kaminská 2001; Farkaš et al. 2008; Cheben & Cheben 2010) and Poland (Valde-Nowak 1991; Valde-Nowak 2003; Valde-Nowak 2010) the emphasis was laid on radiolarite studies earlier and to a greater extend than in Austria (Wischenbarth 2000; Schäfer 2004-2005; Binsteiner 2008; 2009; Binsteiner et al. 2008; Leitner 2008; Mateiciucová 2008; Trnka 2011). Recently, collaborative efforts contributed to provenance studies and to the improvement and advancement of raw material science on a broader scale (e.g., Schäfer 2012). A similar situation is observable in adjacent regions (e.g., Switzerland (Affolter 2002); Italy (Maggi et al. 1997); Germany (Wischenbarth 1999; Pasda 2000).

The importance of radiolarite as a raw material for stone tool production is highly dependent on chronological and geographical aspects of an archaeological site. It is in fact one of the most popular and common materials for the production of lithic tools in Central and Southern Europe, especially south of the cretaceous and tertiary flint and chert occurrences (Kaczanowska 1985, 18-19; Elekes et al. 2000, 502). Nevertheless, the recognition of radiolarite in lithic assemblages still depends on the knowledge of the raw material analysts.

In the course of earlier investigations, it has become evident that visual and microscopical investigations are in most cases not sufficient for a differentiation between radiolarite sources. That is why geochemical analyses have been conducted on radiolarites in previous studies. Ion beam methods (PIXE, PIGE, Elekes et al. 2000), PGAA analysis (Biró et al. 2009), ICP-MS, ICP-ES and microprobe (EPMA) analysis (Cheben & Cheben 2010) have been conducted. These undertakings were able to provide preliminary suggestions for the provenance of radiolarite artifacts. In most cases, however, the results did not produce cogent results. This problem is mainly attributable to constraints of sample size and the choice of applied methods (Kozłowski et al. 1981; Polák & Ondrejíčková 1993; Přichystal 1994b; Mišík 1999; Cheben & Cheben 2010; Hughes et al. 2010).

As shown in previous studies, XRD analysis turned out to be insufficient for identifying mineral phases in radiolarites (Bustillo & Bustillo 1997). This is mainly due to the small concentrations of mineral inclusions in cherts and the mostly poor crystallization of the minerals.

Geochemical results applying LA-ICP-MS indicate the potential for a differentiation between radiolarites from the NCA and the Carpathian Mountains through the investigation of trace element concentrations. This is especially true for Ba in combination with other trace elements, except for samples showing values that are situated within a small overlapping boundary zone. These similarities are due to the similar origin of chert and radiolarite in deep marine facies (McBride 1979).

Barium (Ba) is considered a marker for bioproductivity in ocean environments, even though newer research indicates that Ba is an unreliable productivity proxy (McManus et al. 1998). It is associated with several phases in marine sediments, some of which are of biogene origin

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like carbonates, organic debris, skeletal opal and barite, and phases that are independent from biological activities (e.g., ferromanganese oxyhydroxides and terrestrial material). Predominant Ba-carriers are clays and barite (Gonneea & Paytan 2006, 124-125; 132). The distribution of Ba can be assigned to both inclusions of carbonates and clay minerals in the radiolarite samples. The ratio of Ba contained in the samples reflects different thethyan sedimentation environments within the larger source regions (NCA and Carpathians).

Samples from the St. Veit Klippenbelt are situated between the NCA and the Carpathian data cluster, are thus not distinct and do not allow for the establishment of a separate group. For the WM source, emphasis needs to be placed on additional analyitical methods mentioned above, especially microscopical characteristics. The separation of individual sources, however, is only possible to a limited extent.

Taking into account that most of the raw materials at the Krems-Wachtberg site were collected from river gravel banks and not from primary sources, it was expected that an assignment of the analysed artifacts to specific deposits would not be achievable. However, it was possible to specify the source regions the gravels derived from.

The results reflect a composition of typically intermingled gravel material transported by rivers out of the catchment area into the Austrian Wachau. There, the Danube River contains assemblages of resistant rock components such as cherts and radiolarites from the NCA. The single artifact showing geochemical data assigned to the catchment area of the Carpathian Mountains tendentially shows values closest to the values determined for sources in the White Carpathian Mountains. In an archaeological point of view, this fits into the conceivable scenarios of Gravettian raw material procurement for the Wachau sites.

5.3. A gunflint cache from Schloss Neugebäude *(Neugebäude Palace)*

"The gun-flint manufacture used to be considered a very unhealthy one, and it was said that every knapper died of consumption at about 40 years of age. This may have been true, but the consumption was of drink, and not of the lungs." – **Skertchly 1879, 5.**

5.3.1. Introduction

Gunflints were distributed in great numbers all over Europe from the 17th until the 19th century, and in former colonies even until the first half of the 20th century, and thus are an abundant type of lithic finds in Central Europe. In museums collections as well as in earlier studies they were often mistaken for prehistoric stone tools, however newer research has clearly defined unequivocal characteristics of these artifacts (e.g., Cosack 1999, 257-264). Countries holding the industrial production centres of these military supplies, like France (Meusnes region), England (Brandon), Italy (Monti Lessini), Spain (Casa Montero), and to a certain degree Poland (Kraków region), have a longer tradition in research on gunflints. The present case study is focussing on a gunflint deposit in Vienna, Austria, far from these main production areas. Approximately 1,5 tons of gunflints were recovered from a rubble heap inside a courtyard belonging to the vivarium complex of Schloss Neugebäude (*Neugebäude Palace*) in Vienna-Simmering (11th city district), during an archaeological excavation in 2002 **(Fig. 5.3.1. a + b)**. Preliminary investigations concerning the raw material of the gunflints revealed a provenance mainly from French sources, accompanied by Italian material and such from the Baltic coast (Penz & Trnka 2004, 242-243). Possible Galician material was suspected, but could not be confirmed. The raw material composition of the assemblage is a crucial factor for the assessment of the "last holders" and the depositional circumstances of the gunflint stock. The excavators assume a connection between the cache and military activities linked to Napoleon's expansionism in the early 19th century (Penz & Trnka 2004, 244).

The provenance of 15 pre-examined artifacts from that cache was investigated for this undertaking. For a re-evaluation of the gunflint cache, it was additionally necessary to conduct extensive historical research.

Fig. 5.3.1. a and b: Recovery of the gunflint cache at Schloss Neugebäude 2002

a: Rubble heap in the arch alcove; b: A day's haul in the car

Photos: G. Trnka 2002.

5.3.2. Schloss Neugebäude (*Neugebäude Palace*)

5.3.2.1. Setting and historical background

The palace complex of Schloss Neugebäude is one of the most important architectonic structures of the Late Renaissance in Middle Europe. In terms of art history, it is assigned to Manierism. It was commissioned by Emperor Maximilian II. to be constructed at the place where – according to rumours – the castle-like war-camp of Sultan Süleyman was set up in the course of the first siege of Vienna in 1529. The castle was planned as representative "château de plaisance" including spaceous gardens in the vicinity of the imperial hunting grounds and the Schloss (Kaiser-)Ebersdorf (*Ebersdorf Palace*) in the south of Vienna. It is situated on a berm above the extensive alluvial plains of the Danube, on the right side of the river (Penz & Trnka 2004, 234-245).

Construction work at Schloss Neugebäude commenced in 1568, which obtained its name due to the close proximity to the old Kaiser Ebersdorf Palace, referring to the "New Building" (german = Neugebäude). Important contemporary architects like Jacobo Strada were engaged at the project, combining Italian, French und German ideas to a manieristic synthesis. Maximilian II., essentially influencing the undertaking, added a zoological garden (the vivarium) to the palatial complex, which remained the main attraction until the conversion of

the complex in the 18th century. Rudolf II, his successor, completed the construction, however the decline followed only a few years later at the end of the 16th century. Under Maria Theresia, the vivarium and the artistic stonework were moved to Schloss Schönbrunn (*Schönbrunn Palace*), and Schloss Neugebäude was subject to military-aerarian administration. At the latest since 1779, a powder magazine was established at the castle area and subsequently in the towers of the enclosure wall of the Upper Gardens. In 1780, the ground floor of the castle was reconstructed for gunpowder and saltpetre production purposes. In the course of the Napoleonic Wars, the French army took over Vienna, and Napoleons troops were stationed at Schloss Neugebäude two times, in 1805 and again in 1809. During the latter occupation, they undertook some structural changes at the buildings, as mentioned by Knöbl (1988, 100). Structural measures undertaken in 1824/25 by the military administration can be interpreted as a reaction to the destruction of parts of the building (e.g., the provisional wooden roof dating to Maria Theresia's era) during the French occupation. During the Revolution of 1848, the castle was used as the main ammunition deposit for the army in the vicinity of Vienna. The military use of Schloss Neugebäude lasted until 1918. In 1922, the city of Vienna procured the palatial complex and established a crematory in the castle building, together with an urn-grove in the Upper Garden areas (Ilg 1886; Feuchtmüller 1976, 37; Knöbl 1988, 98-102; Lietzmann 1987; Penz & Trnka 2004, 235-235, 244; Kefeder 2010, 16-17, 39-40).

The area surrounding Schloss Neugebäude was adapted for industrial purposes, amongst others by the Sauer-Werke (*Sauer Industries*) manufacturing cars during WW II, using forced labourers from Mauthausen. Subsequently, the industrial facilities were bombed by the allies, while the castle building was relatively spared. The surviving forced labourers were set free by the Red Army in 1945 (Exenberger 2005).

All attempts of revitalizing the castle complex failed until the early 2000s, when initial protective measurements and cleaning of the castle area took place. Meanwhile, Schloss Neugebäude is used for special events (summer cinema, theatre plays, exhibitions, concerts, etc.).

5.3.2.2. Palatial buildings of Schloss Neugebäude

The palatial complex of Schloss Neugebäude consists of six main structures **(Fig. 5.3.2.)**:

1.) The Hauptgebäude (*main building*) with the Nordterrassen (*northern terraces*), the Haupthof (*main courtyard*) and the U-shaped Ehrenhofgebäude (*courtyard of honour*).

2.) East of the main building are the components of the Löwenhof (*"lions courtyard"*), comprising the Ballspielplatz (*an area for ball games*), the Zwinger (*kennel*), Stallgebäude (*stables*), Nebengebäude (*adjoining buildings*) and the Umfassungsmauern (*embracing walls*).

3.) The obere Garten (*upper garden*) in the south, its walls enclosing the Fasangarten (*pheasant garden*) and the Blumenparterre (*floral parterre*). This part of the area is now the site of the Krematorium (*crematorium*).

4.) To the north lies the former untere Garten (*lower garden*) with the adjacent Weiher (*pond*), now used for agricultural purposes.

5.) The historical "Meierei" (the *stewart`s house*), nowadays outside the palatial area.

6.) The surrounding land, including the former riparian landscape, which has disappeared in large parts but still forms an important part of the Schloss Neugebäude entity.

Schloss Neugebäude is a typical Renaissance garden complex. The architectural form of the main palace – especially its narrow width – does not afford a residential capacity and may thus more precisely be defined as "Bellevue". The location on a slope overlooking the wetlands of the Danube is an additional reference to the role of the Neugebäude as viewpoint, intended for hunting parties, festive receptions and representative purposes (Verein Schloss Neugebäude 2006; Kefeder 2010, 17-25).
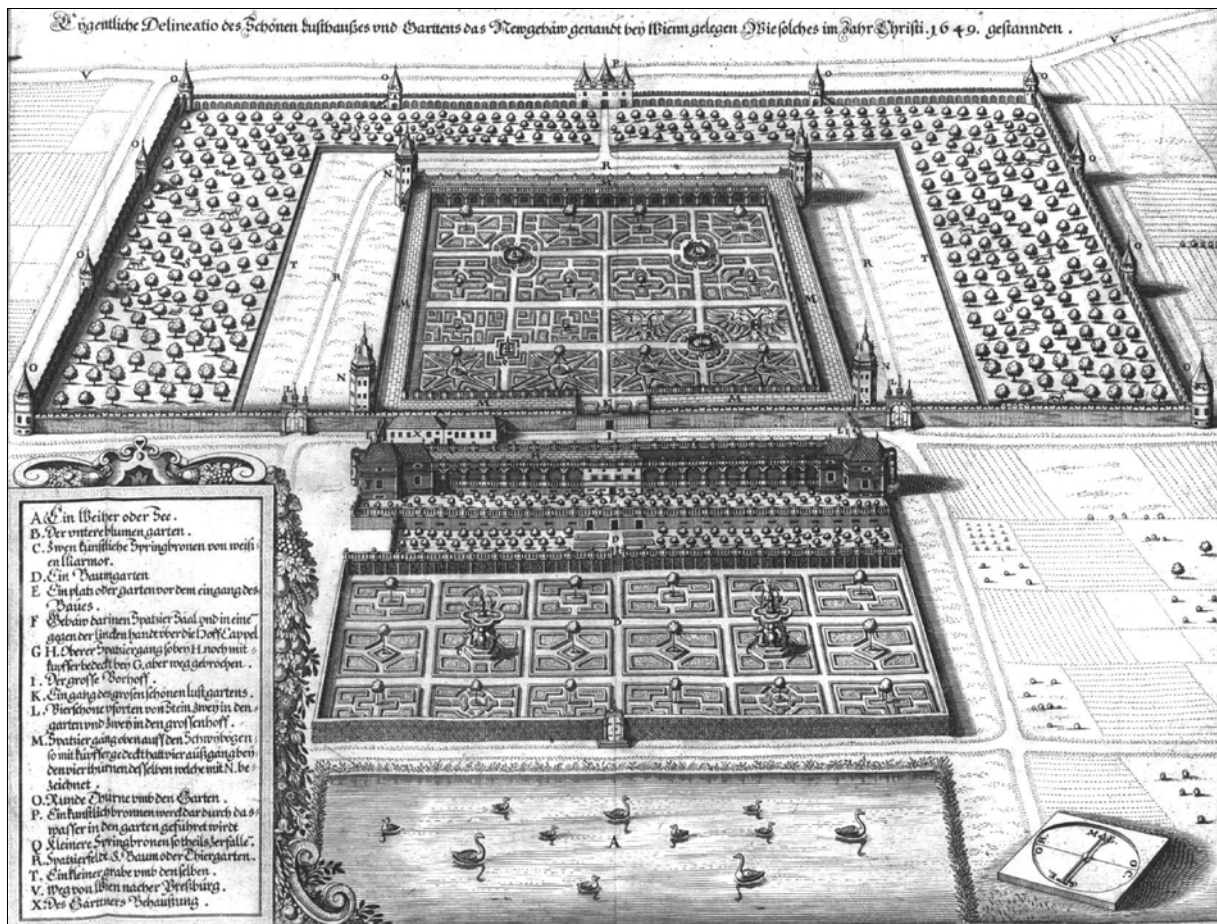
Fig. 5.3.2.: Map of the Neugebäude Palace

Matthäus Merian d.Ä. 1649

Source: Austrian National Library, Picture Archive.

5.3.2.3. The gunflint cache

5.3.2.3.1. History of discovery

In the course of the endeavors to revitalize Schloss Neugebäude, survey activities concerning the architectural contexts were accompanied by archaeological investigations since 1986. The excavations were conducted by teams from the Wiener Stadtarchäologie and the Historical Museum of Vienna. In 2002, G. Trnka from the Institute of Pre- and Early History and M. Penz from the Stadtarchäologie Wien started investigations as a reaction to reports of abundantly occurring flint artifacts in the area of the former vivarium complex of the Palace. The preliminary examination yielded a densely packed accumulation of gunflints in a rubble heap situated in an arch alcove of the northern enclosure wall of the Löwenhof or

Ballspielplatz (**Fig. 5.3.2., Fig. 5.3.1. a**, **Fig. 5.3.3.** and **Fig. 5.3.4.)**. Two archaeological campaigns were conducted, on July 9-10 and from September 24th to October 11th, 2002. For this undertaking, a garden sieve with openings suitable for the recovery of the gunflints was used, and by the end of both seasons ca. 1,5 tons of lithics could be collected. A continuation of the fieldwork was planned for the following year, but the remains of the heap were removed in the course of uncoordinated earthwork in the area of the site. At least half of the estimated total amount of gunflints was thus lost for further investigations, however the secured material is the most substantial collection of that find category in Middle Europe (Penz & Trnka 2004, 235-237).
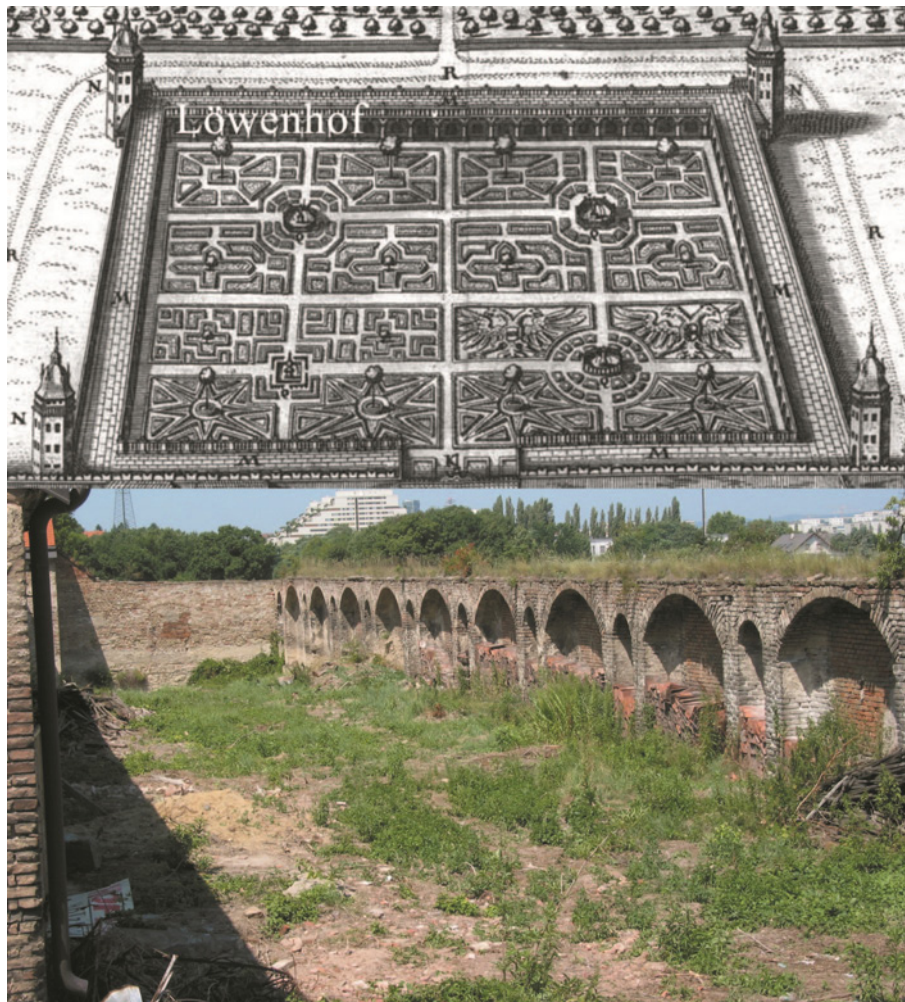
Fig. 5.3.3.: Location of the excavation
Detail from Fig. 5.3.1.; Photo: G. Trnka 2002.

Fig. 5.3.4.: Rubble heap with gunflints

Photo: G. Trnka 2002.

5.3.2.3.2. Preliminary remarks on the assemblage

The lithic assemblage from Schloss Neugebäude mainly consists of unused gunflints, comparatively uniform in shape but heterogeneous in size **(Fig. 5.3.30.)**. It additionally contains 31[8] gunflints wrapped in lead sheets, 18 lead bullets (standard diameter = 15,5 mm) and some single pieces of lead sheets **(Fig. 5.3.5.)**. All pieces encased in lead sheets show traces of usewear on the ignition ("firing")[9] edge (= bevel), whereas all uncoated pieces are unused. In order to minimise the risk of rapid damaging of the gunflints, they were usually coated with different materials, e.g., leather, before they were fixed into the jaws of the gun. For military use, lead sheets were a common alternative, particularly since the lead coating could be easily produced by flattening lead bullets with a light hammer (Penz & Trnka 2004, 241).

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[8] One piece was recently (Dec. 2012) recovered in the course of ongoing cleaning activities at the Institute for UfG by G. Trnka.
[9] For terminology see Lotbiniere 1982, Fig. 1c. and Section 5.3.3.2.

Fig. 5.3.5.: Gunflints in lead sheets

Photo: G. Trnka.

The majority of the gunflints from Schloss Neugebäude bear metal traces on the surfaces, deriving from the production procedure (Penz & Trnka 2004, 240-242; Section *5.3.3.5. Gunflint production* and **Fig. 5.3.6**). They exclusively show a half-rounded horseshoe shape with a straight ignition edge on the front. Typically, the dorsal side shows one, rarer two ridges (blade scars) and a steep lateral retouch covering three third of the piece creating the characteristic horseshoe shape ("talon rond"; Weiner 2012, 964). The ventral side bears a lateral retouch at the straight ignition edge or bevel, which should prevent the gunflint from heavy fracturing in the course of striking the ignition sparks.
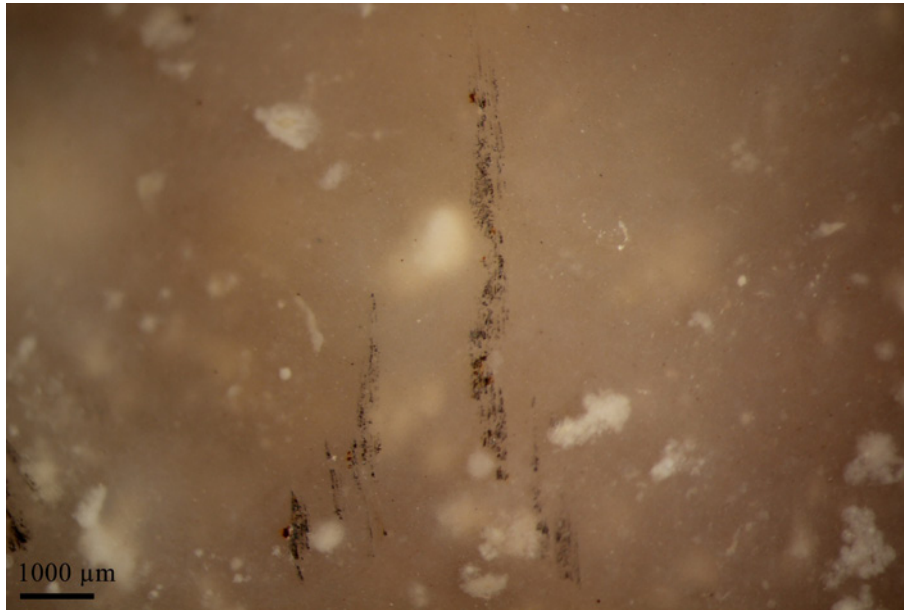
Fig. 5.3.6.: Metal traces on the surface of a gunflint from the Neugebäude cache

Photo: M. Brandl.

As mentioned above, the Neugebäude gunflints are highly inconsistent in size. This suggests a mixing of various contingents designed for specific types of firearms (see Section *5.3.3.5. Gunflint production*). According to Seel (1981, 1456), emphasis was especially laid on sorting gunflints consistently in size for packaging, so that wholesalers were able to sell bigger stocks without additional work for the customer after delivery.

For further chronological, cultural and historical investigations on the Neugebäude assemblage, the history and development of gunflint production in Europe with special regard to the situation in the Austrian Empire needs to be addressed.

5.3.3. Historical background of gunflint production

5.3.3.1. Development of the flintlock mechanism

The earliest application of flint for striking a spark at a gun dates back to the early 16th century with the invention of the wheellock system for muzzle loaded guns. The counterpart of the wheel was at that time a pyrite, and not yet a gunflint. A further advancement was achieved with the introduction of the snaplock during the mid 16th century, the first real flintlock mechanism. The snaplock was refined in France, and in the first decade of the 17th

century the sophisticated "battery lock" was created, which culminated around 1640 in the development of the French rifle, the "fusil". The battery-flintlock system remained – with minor adjustments over time – the standard for military fire arms until it was replaced by the percussion cap ignition system, independent from gunflints, by the 1840s (Weiner 2012, 961).

5.3.3.2. Functional principle of the flintlock

The main elements of a flintlock mechanism are displayed in **Fig. 5.3.7.**
These are:
1) the pan **(Fig. 5.3.7. no. 1)**, attached to
2) the battery (or frizzen), a specifically shaped fire steel **(Fig. 5.3.7. no. 2)**, and
3) the cock **(Fig. 5.3.7. no. 3)** holding the gunflint **(Fig. 5.3.7. no. 4)**.
The pan is mounted horizontally and protruding in a half roundish shape at the end of the gun barrel, typically on the right side of the stock. It is connected to the barrel by the touch hole, a bore allowing for ignition of the powder. The battery is fixed revolvable at the front end of the pan and is in the shape of an angle iron with obtuse-angled sides. Attached below the battery, the frizzen spring **(Fig. 5.3.7. no. 5)** secures the latter in a locked position. When locked, the lower, straight side of the battery covers the powder in the pan, and at the same time the concave curved upper side points in the direction of the cock, which is positioned directly above the pan. The cock has two jaws **(Fig. 5.3.7. no. 6)** which hold the gunflint. The stone, wrapped in a leather rag or coated in a lead sheet, is secured by the jaw screw **(Fig. 5.3.7. no. 7)**.
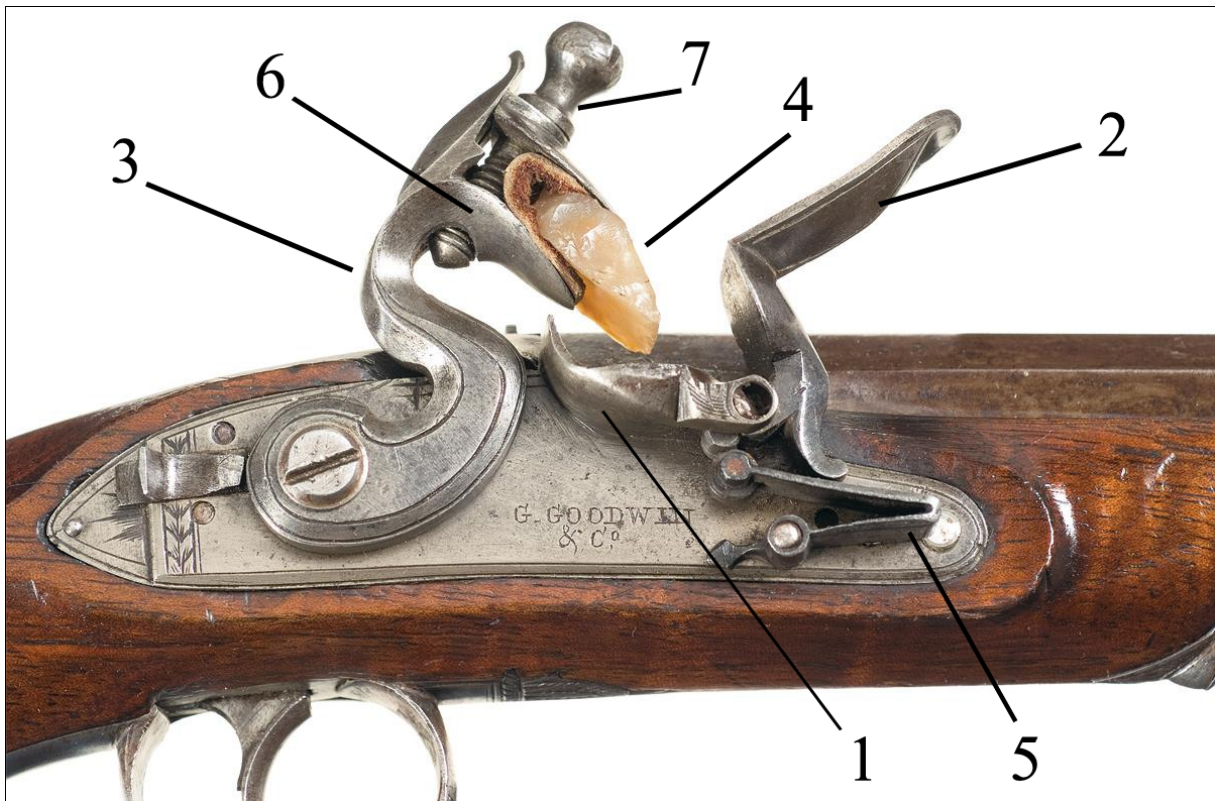
Fig. 5.3.7.: Main elements of the flintlock mechanism[10]

Adapted from: http://www.tumblr.com/tagged/flintlock+mechanism (query from 07.10.2012).

The ignition process is initiated by the cock snapping forward and the gunflint hitting the concave upright side of the battery with the bevel (ignition edge). The battery, pushed back by the impact, exposes the powder on the pan, and the gunflint strikes sparks on the hardened surface of the battery. The sparks light the powder and cause an explosive flame igniting the charge in the barrel through the touch hole, accelerating the bullet (Slotta 1980, 350-351; Weiner 2012, 962-963).

5.3.3.3. Production centres in Europe

Since the flintlock mechanism started to replace the previous systems for European military equipment at the end of the 16th century and became standard in the early 17th century, the demand for gunflints raised tremendously. This is especially true for times of war, but also in peaceful periods (e.g., for hunting or military exercise[11]; Seel 1981, 1452-1453). It is

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[10] Goodwin Flintlock Pistol, ca. 1800.
[11] For practicing the handling of the guns without the need of firing ("Griffeklopfen"), the gunflint was replaced by a wooden implement ("Holzstein").

understandable, that henceforth every country would seek for the possibility of domestic gunflint production. Countless attempts have been undertaken in various countries, however only few production sites were able to endure over longer time periods and gain historical importance. As a matter of fact, the most extensive production centres could only develop in regions providing suitable raw material for gunflint knapping. The two most important of these sites were located in the region around Meusnes in France (dépt. Loir-et-Cher) and at Brandon in England (Suffolk). Especially the French gunflints were known to be of best quality (i.e. the persistence in use), with the result that France became the principal gunflint supplier for Central Europe in the course of the 18th and early 19th century (see Section *5.3.3.6. Economical considerations*).

The attempt of some sovereigns to become independent from the French market resulted in mostly unproductive undertakings, others were able to establish a small gunflint industry. Gunflint production is documented in Albania (Avlona region), Belgium (around Spiennes), Germany (at Burglengenfeld in Bavaria and Dinkelberg in Baden), Denmark (at Seeland, St. Heddinge region, and the island of Mön), England (Kent, Suffolk and Wiltshire), France (dépts. Ardèche, Bas Rhin, Indre, Loir-et-Cher, Seine-et-Oise, Vaucluse, Yonne and Nord), Italy (at Avio in the Etsch valley, the Monti Lessini north of Verona and on Sicily), Austria (see Section 5.3.3.8.1.), Poland (Kraków region), Sweden (near Schonen), Portugal and Spain (Casa Montero southeast of Madrid and in the provinces of Cuenca and Guadalajara; Weiner 2012, 963-964).

Since Meusnes, France and Brandon, England were the most important and best documented production areas in Europe, the following general discussion focuses on these two regions. Austrian gunflint supply is discussed in detail in Section *5.3.3.8. Austrian situation*.

5.3.3.4. Raw material exploitation

5.3.3.4.1. France

According to Emy (1978, 54), the method of raw material exploitation at Meusnes appears to have undergone only negligible changes throughout the roughly 250 years of industrialized production of gunflints.

The flintknappers *(caillouteurs)*, in most cases not in possession of the mines, paid a lease to the landowners and carried out the quarrying themselves. The mining shafts were called "*carrières, caves* or *crocs*", reaching a depth between 5-25 m. The work in a "*croc*" was undertaken by several *caillouteurs* in a collaborative effort, involving up to 6-7 workers. When sunk to the adequate depth in several stages for obtaining the best material, horizontal passages were dug out, up to 16 m long and 2 m high. The caillouteurs worked in shifts of 4 hours on their knees (Appendix A, REF 28; Emy 1978, 55-57; Seel 1981, 1450; the information concerning the depth of the shafts differs in the references).

Their tools consisted of the ordinary equipment of miners at that time, a pick ("*pic de mineur*") and a shovel (Emy 1978, 64).

5.3.3.4.2. England

Other then in France, the quarrying was not carried out by the knappers in England, but by specialized miners. Also, unlike in French quarries, division of labour was not common (Appendix A, REF 29; Seel 1981, 1458; Weiner 2012, 969). The digger (or miner) did not have to pay a lease or "groundage", but this fee was added to the price of gunflints by the contractors. The shafts were also created in steps, reaching a depth of 37-43 feet (=11-15 m; Clarke 1935, 45-46). The goal of the diggers was to extract flint of the highest quality, called "floorstone" (Skertchly 1879, 23).

The digger's tools were four, a "one-sided pick, a heavy iron hammer, a shovel and a short crow-bar" (Skertchly 1879, 15). After successful exploitation of a shaft, Skertchly (1879, 25) states: "The stone is sold by the diggers to the flint knapper's by the jag, which, as before stated, is a one-horse cart-load about equal to a ton".

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5.3.3.5. Gunflint production

5.3.3.5.1. Early stages: Gunflints from flakes

The earliest examples of gunflints have not been produced in manufactories, but were knapped individually by the gunmen.

Early production sites in Denmark, Southern England and Sothern France (Vaucluse) are known for the manufacturing of characteristic gunflints (engl. *wedges*; amer. *gunspalls*) in the 17th century. They are of either half roundish or rectangular, wedge-shaped appearance with a straight ignition edge. The bulbar area was sometimes reduced. The spalls were knapped from small flint nodules or thick flakes, using metal hammers (White 1975, 65; Weiner 2012, 964). These types of gunflints were not yet standardized and it was a hard task fitting them into the jaws of the flintlock (Weiner 2012, 964).

5.3.3.5.2. Advanced technology: Gunflints from blades

5.3.3.5.2.1. France

At the latest since 1740, the manufactories in the region of Meusnes in France exclusively used blades as basic debitage for gunflint production. This method, soon known as the "French method", allowed for a standardization of the gunflints, and at the same time it accelerated the production process. For military purposes (*du gouvernement*), the gunflints were exclusively half-roundish shaped (*talon rond*) with only one ignition edge, whereas civilian pieces were of a rectangular form with two opposite firing edges (Weiner 2012, 964). The sizes varied, depending on the type of fire arm they were attributed to.

The production process is described in various historical reports (Appendix A, REF 35-40). It can be summarized as follows (see **Fig. 5.3.8 and 9**):

1. Using a heavy metal hammer with a square head *(marteau cassant)*, the chosen rock is split into convenient pieces, the cores.

2. From these cores, uniformly shaped blades are knapped with a pointed hammer *(marteau à pointe)* from unhardened iron.

3. The blades were placed – the dorsal side up – on a chisel (REF. 35, 37 *ciseau*; Weiner 2912, 965: ***fendeur, copeau***), which was, slightly inclining, applied to a knapping block (REF 38: ***table de Boucaniere*** ; REF 40 and Weiner 2012, 965: **billot**).

4. The blades were then segmented into rectangular pieces (4 at the max), applying aimed strokes on the dorsal side with a special hammer, the **"roulette"** (the roulette had a round hammer head and a centred hole for the handle).

5. Subsequently, the segments (rough-outs) were placed on the anvil, and, again using the roulette, retouched on the back and both lateral sides in the case of the horseshoe shaped pieces, and only on two parallel lateral edges for the rectangular gunflints. In both cases, the reinforcement of the ignition edge(s) is located on the ventral side (Weiner 2012, 966; compare Section 5.3.2.3.2.).

The splitting of the raw nodules and the blade knapping was conducted by men, segmenting and retouching was done by women and children (Weiner 2012, 966).
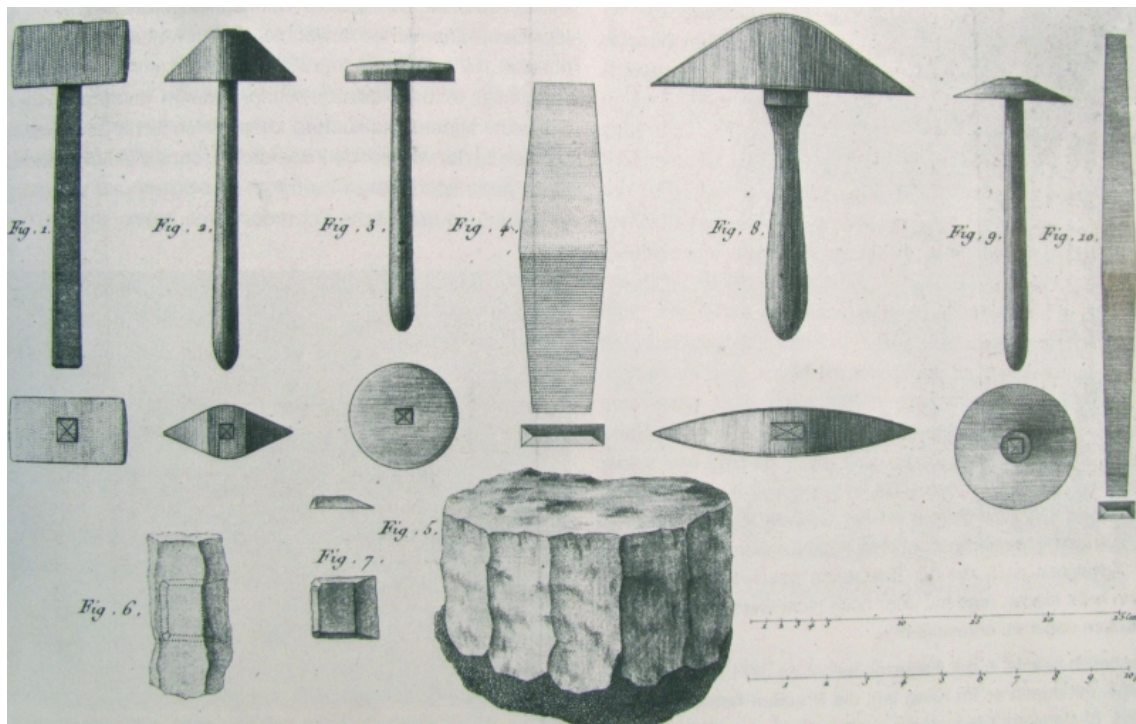
Fig. 5.3.8: Tools for gunflint production

Source: Gillet-Laumont 1798, 719 Tab. 1.
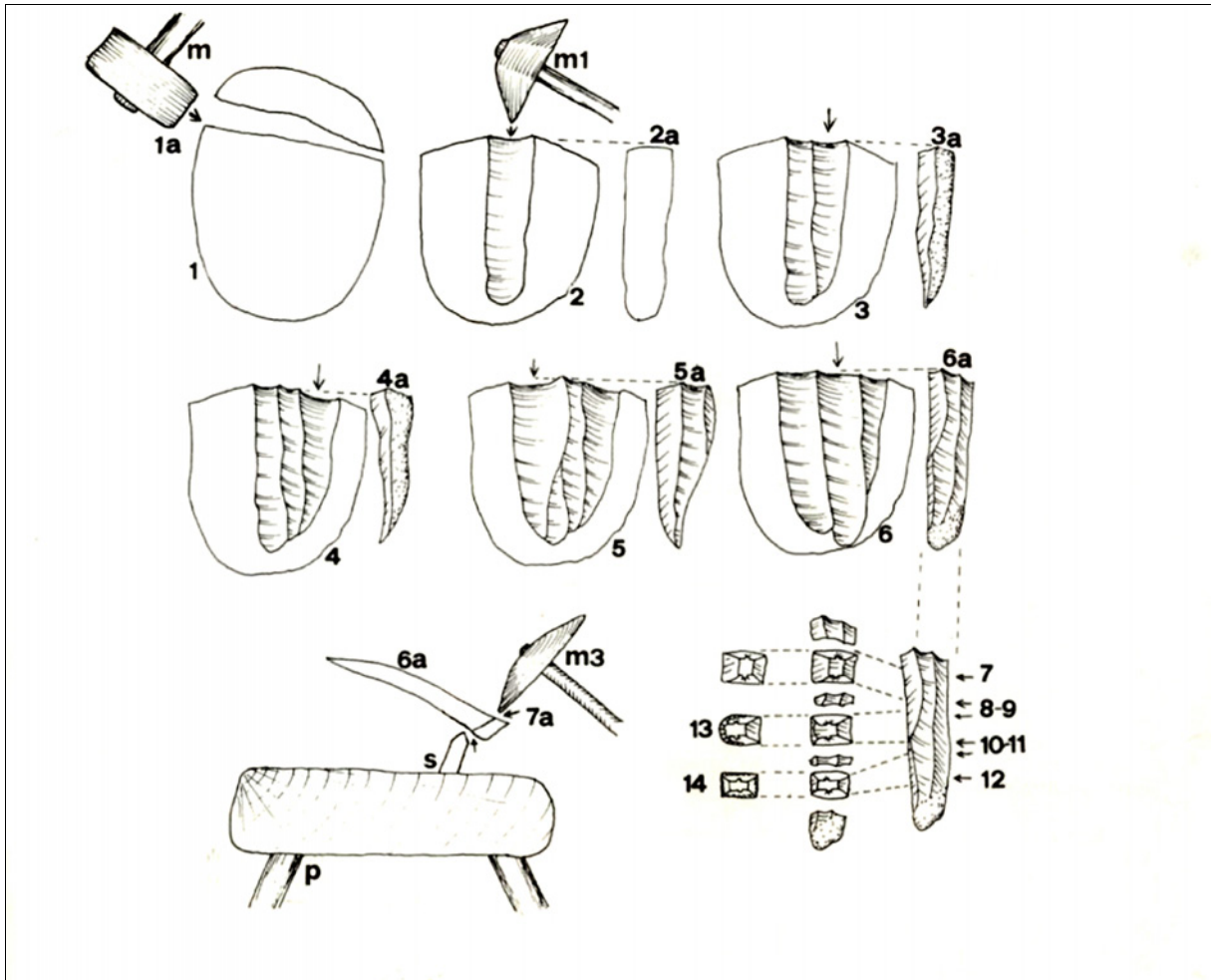
Fig. 5.3.9: Procedure of gunflint manufacturing

Source: Chelidonio 1987, 125

The terminology describing the single parts of a gunflint appears not to be coherent in historical reports. Hacquet (REF 38) describes a gunflint as divided into six separated areas, the upper and the lower platform, the rounded back ("le Cul", actually "the head") and two straight or half roundish retouched sides ("les Bords"). The straight ignition edge or bevel is called "le tranchant" or "bord de platine".

According to Dolomieu (Appendix A, REF 39), a typical French gunflint has five distinct parts:

1. *La mèche* (ignition edge), which should be sized between 5–7 mm ("deux à trios lignes", two to three lines). If too large, the gunflint gets fragile, if too small, it does not produce sparks in a sufficient quantity.

2. *Les flancs*, the lateral edges, of a slightly irregular shape.

3. *Le talon*, the back, opposite the *mèche*.

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4. *Le dessous*, the underside of the gunflint, showing a slight convexe shape.

5. *L'assis*, the upper side of the stone, slightly concave shaped for a better fitting into the jaws of the cock ("le chien", see **Fig. 5.3.7.**). This description is condensed in REF 40 ("*Reminder for the use by Officers of the French artillery*").

5.3.3.5.2.2. England

In the course of standardization of fire arms, gunflints produced from blades soon proved their advantage over gunspalls. For that reason, around 1790 the French method of gunflint production was adopted at the manufactories at Bandon. In England, other than in France, there was no difference between military and civilian gunflints. The shape was always rectangular with only one ignition edge, varying in size for different types of arms (Weiner 2012, 968).

The production process is best described by Skertchly (Appendix A, REF 41):

1. Prior to the actual working of the flint, it was dried to a certain degree in order to guarantee best knapping properties.

2. The next step was called *quartering*, which meant breaking up the flint nodules into wieldy pieces, using a heavy, iron **quartering hammer**.

3. The rock parts are used as cores, from which blades are knapped. This procedure was called *flaking*, applying the **flaking hammer**. According to REF 41, prior to the introduction of the French hammer there was an **"English hammer"** used for that purpose.

4. The blades were then – with their ventral side up – placed on an iron anvil with a straight surface **(the stake)**, which was, slightly inclining, driven into a **block** of wood (usually elm wood), and, applying aimed blows on the ventral side, segmented into 5 pieces max. *(knapping)*. For this task, a special hammer was used, its head consisting of a square, thin iron bar with short and straight working edges, and a centred hammer eye **(knapping hammer)**.

5. In the final step, the segments were completed on the stake. Once more, the knapping hammer was applied in order to produce a fine, reflecting lateral retouch on three sides of the gunflint (the two lateral edges and the neck, always from ventral to dorsal).[12] The reinforcement of the ignition edge is always located on the ventral side (compare Clarke 1935, 49-51; Weiner 2012, 968).

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[12] The English method left two characteristic demicones at both transverse sides of the gunflints, features that were removed at French gunflints (Weiner 2012, 969).

The quatering as well as the further processing was equally conducted by men and male adolescents (Weiner 2012, 969). The exhausted cores were commonly used for construction purposes instead of bricks, and therefore called "builders" (Skertchly 1879, 34-36).

The parts of an English gunflint were separated into four parts, two *sides*, the *heel,* and the *edge* or *firing edge* (Skertchly 1879, 32; Clarke 1935, 55, Fig. 2).

5.3.3.6. Economical considerations

Taking all historical records into account, the output of an average knapper was approximately 3000 gunflints in a 12 hours shift, an experienced worker was able to produce up to 4000. The stones were packaged according to their size and quality, and also depending on the manufacturing site. Usually, they were bagged by 1000 and fit into barrels for transportation, containing 5.000, 20.000, 60.000 or 100.000 gunflints (the latter in the case of small flints for pistols; Weiner 2012, 969).

Maybe the biggest difference between France and England was the economy behind gunflint production. In France, the gunflint trade was organized by wholesalers, and gunflints were imported by the millions on behalf of sovereigns all over Continental Europe (compare Appendix A, REF 5 and 56). Additionally, they were introduced into the French colonies and presented at international sales fairs where they also entered the civilian marked.

In England on the other hand, the government controlled the business. The manufactories delivered the gunflints directly to the "Board of Ordnance", exclusively reserved for the use at the British army and in the British colonies, but not for civilian purposes (Seel 1981, 1458; Weiner 2012, 963, 969).

The most significant consequence of these differences in the economical systems was the spreading of French gunflints all over Europe and beyond. As indicated above, France was in fact the predominant supplier for gunflints before the Napoleonic Wars.

Because France, and especially the village of Meusnes, produced gunflints famous for their quality, gunflint trade became an important contributor for the French economy. From a

historical standpoint (see Appendix A), four major consequences of this development can be reconstructed:

1.) Intentional disinformation (especially regarding the production process, in some cases leading to curious opinions of early authors, as indicated in REF 50, footnote Pg. 528, REF 51 and REF 58). In this context, a strict concealment of the manufacturing sites was enforced (REF 51, 53, 57, stating that visiting the gunflint manufactories was "forbidden under penalty of death"; Hacquet qualifies these statements in REF 52. He was able to visit Meusnes, providing a detailed description of the production process; see REF 38).

2.) Industrial espionage and efforts to lure flintknappers away from Meusnes by order of European sovereigns (REF 56: Undertaking of Joseph II. of Austria; REF 48, 49, 50, 52 and 53 contain different versions of the most popular of all recollections, the "Klose-story").

3.) Temporary prohibition of gunflint exports by the French (Emy 1978, 242-246, Chapter *"Interdiction d'Exportation"*).

4.) As a reaction to 3.), gunflint stocks were accumulated outside of France, motivated by the threat of bans on exports (REF 53, referring to stocks in Holland and at Frankfurt a. Main).

5.3.3.7. Chronology

5.3.3.7.1. France

According to Weiner (2012, 969) and Edeine (1963, 18) [13], the earliest gunflint production in France is recorded from 1643. Theses early manufactories produced the old type of irregularly, wedge-shaped gunflint (see Section *5.3.3.5.1. Early stages: Gunflints from fakes*). Skertchly (1879, 3) states that *"...it was not until the year 1719 that a manufacture of gun-flints was **regularly** established in France."* At Meusnes, the production of the platform type of flint, struck from blades, was introduced around 1740 (Weiner 2012, 969).

Gunflint manufacturing activities at Meusnes lasted until the 1930s, and came to an end when the last branch of trade, exports to the colonies, ceased (Emy 1978, 18; Weiner 2012, 970). Today, the curator of the Musée de la Pierre à Fusil at Meusnes, Jean-Jacques Dutrieux, has revived that old tradition by professionally knapping gunflints for the interested public.

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[13] Edeine 1963, 18: *"Le plus ancien document que j'ai pu trouver faisant mention d'un caillouteur, nom donné aux fabricants de pierre à feu, est un document de 1643 à propos d'un caillouteur de Meusnes."* (The earliest document I was able to find makes a reference to a cailloutuer, as the gunflint makers are called, a document from 1643 concerning a caillouteur from Meusnes).

5.3.3.7.2. England

The beginnings of English gunflint production are also controversial. Skertchly (1879, 3) states: *"Flint-locks were introduced into the English army about the year 1686, and were in general use at the beginning of the I8th century."* Woodward (1960, 29) and Seel (1981, 1458) refer to the same date[14] as to the beginnings of gunflint manufacturing in Great Britain, however Witthoft (1966, 36) argues that *"the archaeological evidence is against the existence of any British gunflint industry prior to 1780"* (South 2002, 3). Weiner (2012, 969) also dates the commencement of gunflint manufactories at Brandon at around 1790.

However, these disparities can be clarified reading the literary sources carefully: Gunflints of the gunspall type (from blades) were distributed by the "Government gunflint factory" since 1686, however, the production of standardized gunflints from blades was introduced at Brandon at around 1790. Consequently, **industrial** production did not commence until 1790 (Lotbinière 1977, 18).

In England, gunflint manufacturing survived longer than in France. From the second half of the 19th century on, the colonial states, Africa, East Asia and Oceania were the most important markets (Clarke 1935, 55).[15] At the end of WW II, there were five knappers left at Brandon. Gunflints were still exported to the (former) colonies, however 1961 South Africa withdrew from the Commonwealth, which led to the imposition of a United Nations arms embargo in 1963 (Appendix A, 59). Fred Avery remained as the last Brandon gunflint knapper until his death in 1996 (Whittaker 2001, 382).

In Continental Europe, the end of gunflint trade came by far earlier, when the percussion system rapidly replaced the old flintlock mechanism around 1840. Subsequently, gunflints were only exported to the colonies in order to supply them with inferior weaponry. Once more, the "colonial masters" imposed their hegemonic claims through the control and ability to restrict the distribution of gunflints – keeping their "fosterlings" in rein (Seel 1981, 1458; Weiner 2012, 961).

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[14] The year the "Government gunflint factory" was established.
[15] The notice of "Austria" appearing on the list of importers of Brandon gunflints in 1907 besides China, Tibet, Oceania, Java, Sumatra and Malaysia is strange; I believe that he refers to "Australia". However, other authors cite this passage in order to stress the importance of Brandon gunflints even at the beginning of the 20th century (e.g., Shaw 1981, 157).

5.3.3.8. Austrian situation

Ongoing military conflicts during the 18th century had serious impacts on the governmental coffers of the Monarchy, and, like various others, the Austrian emperors were endeavoured to gain independency from foreign gunflint supplies. The principal supplier for the Austrian army during that time period was – not very surprising – France (Appendix A, REF 18 and 20). According to Hacquet (1792, 62), the combined military and civilian gunflint consumption reached the 10 million mark per year at the end of the 18th century. Due to the critical shortage of material, a project from 1770 even considered the reintroduction of the matchlock system (Seel 1981, 1451). In 1776, efforts to lure professional gunflint knappers away from France failed due to the lack of high quality raw material in the Austrian countries (Appendix A, REF 54; Emy 1978, 76; Penz & Trnka 2004, 238). A public notice ("Kurrende") from 1787 (Appendix A, REF 3), offering a reward of 100 Ducats for the discovery of an outcrop carrying material suitable for gunflint production, resulted in costs of 51,000 Gulden within a year and a collection of useless rock samples on sides of the Viennese Court (Hacquet 1792, 63; Seel 1981, 1452; Penz & Trnka 2004, 238-239).

In the following discussion, traces of gunflint production in regions under Austrian influence will be reconstructed, with differing accuracy depending on the availability of historical sources.

5.3.3.8.1. Contemporary Austria

The few literary sources vaguely point in the direction of small scale extraction and testing attempts of alpine raw materials in Styria, Salzburg and Tyrol (Appendix A, REF 1, 2, and 4-6), however there is no factual evidence of any kind of long-lasting local gunflint industry in today's Austria.

Styria:
Most sources refer to activities in the former southern part of Styria, now Slovenia (see Section *5.3.3.8.3. Slovenia* and Appendix A, REF 9-12). A (lost) reference to gunflints produced in Styria and sold in Graz is more than dubious (Brandl 2009, 38). The test

extraction site at Gams-Hieflau (Appendix A, REF 2 and 5; Klemm 2001, 145-155) only carries material of inferior quality and was certainly never used for gunflint production.

Salzburg:

There exist only two sources referring to actual gunflint manufacturing in the Salzburg County. Carl Ployer (Appendix A, REF 4) mentions a sovereign conferment for gunflint production in the Glasenbachklamm near Elsbethen[16], dating to June 4th, 1798. According to Ployer, the workshop delivered products for military and civilian use.

According to Hell (1935/1938), some rectangular shaped gunflints were recovered in the back of the Gasthaus (= restaurant) Lochhäusl at Glasenbach in the course of excavations undertaken by the owner of the property in 1936. At first, they were mistaken for Neolithic stone tools, but they were recognised as gunflints in the course of an examination. Hell mentions a military production site for gunflints at Glasenbach, where gunflint manufacturing continued until the 19th century. However, the lithics are not traceable to date, and not a single radiolarite gunflint is known so far.

REF 6 (Appendix A) only lists raw material sources, amongst them Hallein, Kuchl, Lofer, and the Unken Valley, without indicating practical use of the material.

Tyrol:

Like Styria, Austrian Tyrol was once much larger in territory then it is today. Most references mentioning gunflint production in Tyrol relate to areas that are nowadays situated in Italy (the former "Welsch Tirol"; see Section *5.3.3.8.2. Italy*). Present-day Austrian Tyrol is rich in chert and radiolarite, however alpine sources appear to have been too remote for industrial exploitation. Nevertheless, the oldest literary source in Appendix A, REF 1 (The "Tiroler Landreim" from 1558), gives account of "Sonnwendjocher-Nieren", that were exported from Tyrol for the ignition of "firing guns" (*Feuerbüchsen)*. Although those "kidneys" are usually interpreted as alpine cherts or radiolarites, this is not necessarily true. Taking the early date into account, it is clear, that the products made from the "kidneys" were no gunflints for the use in a flintlock. In the 16th century, the matchlock system was generally in use for firearms. Consequently, these "kidneys" could have consisted of a different material that is able to produce sparks, like pyrite, marcasite (FeS_2) or even garnet.[17] However, considering the

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[16] Glasenbachklamm: See Chapter 5.2.
[17] Also compare Flügel (2006, 33): „Wir kennen, was die „Eisenstufen" anbelangt, dank einer Beschreibung von Poda einen Teil ihrer Mineralien, wie den Granatus marialis, den „Eisenhaltigen Granat", der „in Tyrol und anderwärts anstatt der Feuersteine auf die Flintschlösser geschraubt, und tyrolischer Flintstein genennt" wurde (Poda 1772)."

characteristic "kidney-" shape, it is most likely that the "Sonnwendjocher Nieren" were either alpine cherts or marcasites. Recent surveys conducted by the colleges in Innsbruck concerning those "kidneys" produced no satisfying results.[18]

5.3.3.8.2. Italy: Lessinia (Monte Baldo and the Lessini Mountains)

The area Monte Baldo and the Lessini Mountains (in short: *Lessinia*) are situated in – the hinterland of Verona – has an eventful history in the late 18th and early 19th century. Border region for the longest time, the reconstruction of the political affiliations of the region(s) containing the raw material sources is relatively complex, especially in the times of the Napoleonic Wars (*see additionally the condensed compilation below*).

From ca. 1400 until 1797, Monte Baldo and parts of the Lessini Mountains were located within the territory of the *Bishopric of Trento*, bordering the *Republic of Venice* holding the southern Lessinian mountain ranges (compare Appendix A, REF 53, pg. 11).[19]

After its dissolution in 1797, the *Republic of Venice* was replaced by the *Duchy of Venice*, under Austrian control; the border remained practically the same as in 1797.

The prince-bishopric of Trento, already under Tyrolean supremacy, was subsequently annexed by the County of Tyrol, Crown Land of the Austrian Empire, in 1803[20] (Ackerl & Kleindel 1994, 278).

These southern parts of Tyrol were then known as *"Welschtirol"* (today's South Tyrol and Trentino). Consequently, Austria was in the possession of the entire Lessinia-region by 1803.

This changed only two years later, when the entire Tyrolean territory was passed to the *Kingdom of Bavaria* in the course of the execution of the Treaty of Pressburg in 1805. Additionally, the *Duchy of Venice* was incorporated into Napoleon's *Kingdom of Italy* (Regno d'Italia). Since then (and some authors even refer to the date 1796/97, e.g., Chelidonio 2010, 229), the French had control over the territory, with the Bavarians as their allies. Historical maps of that time **(Fig. 5.3.10.)** display the old border between Welschtirol and the

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[18] Pers. comm.. T. Bachnetzer; see Appendix A, REF 1, footnote 1.

[19] Remark G. Chelidonio: The border line between the Republic of Venice and Tyrol is still signed by many boundary stones dating to 1754, originally numbered 1-100 in Monte Baldo, and 1-200 in the Lessini Mountains, where only a small northern part belonged to the area under Tyrolean influence. Concerning flint outcrops, only the NW area of Sega di Ala was under Tyrolean administration, probably owing to the power of the Bishopric of Trento.

[20] In the course of the "Principal Conclusion of the Extraordinary Imperial Delegation" (*Reichsdeputations-hauptschluss*), 1803.

surrounding territories, reflecting a longstanding situation dating back to the autonomy of the Bishopric of Trento (note: the border between Welschtirol and the Kingdom of Italy – the dashed line – runs exactly on the crest of Monte Baldo).

In 1810[21], *Welschtirol* became part of the *Kingdom of Italy*, and remained under French control until 1814. As a consequence of the Battle at Waterloo and the Congress of Vienna, Tyrol became again part of the Austrian Empire in 1815, and the Kingdom of Italy was annulled (Ackerl & Kleindel 1994, 278).

The raw material sources of Lessinia were then again situated in a borderland, partly in Austrian Tyrol and partly in the newly established *Kingdom of Lombardy-Venetia* **(Fig. 5.3.11.)**, both under Austrian control.

The political affiliation of the Lessinian area before, during and after the Napoleonic Wars can be outlined as follows. The region was borderland between

ca. 1400-1797:	the **Bishopric of Trento** and the **Republic of Venice** (compare Appendix A, REF 7 and REF 53, pg. 11);
1797-1803:	the **Bishopric of Trento** and the **Duchy of Venice**;
1803-1805:	(now Austrian) **Welschtirol** and the **Duchy of Venice**;
1805-1809:	(intermediately Bavarian) **Welschtirol** and the **Kingdom of Italy (Regno d'Italia)**;
1810-1814:	**Welschtirol** is part of the **Kingdom of Italy**, and no actual border region at that time;
1815-1859/1866:	Borderland between the **Kingdom Lombardy-Venetia** and (the again Austrian) **Welschtirol**.

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[21] After the suppression of Andreas Hofer's revolt.

Fig. 5.3.10.: Carte du Tyrol, en l'An 9 au Dépôt général

de la Guerre et augmentée du Vorarlberg, 1808. Scale: 1140.500

Source : http://gis.tirol.gv.at/ (query from 29.10.2012).

Fig. 5.3.11.: Woerl Atlas über alle Theile der Erde, 1839,

Kingdom Lombardy-Venetia

Source : http://www.atlassen.info/(query from 29.10.2012).

The following considerations have to be seen in regard to this historical background of the region. They play an important role in the determination of parts of the Schloss Neugebäude gunflint cache.

Workshops:

According to Woodall & Chelidonio (2006, 223-224), the beginnings of gunflint production in the Lessini Mountains are uncertain. It is very likely that it commenced in the first half of the 18th century. Reliable sources are REF 7 (Bergbaukunde, 1790) and REF 8 (Ployer, 1800), providing evidence for the existence of workshops at the end of the 18th century.

For the Austrian Empire, the Lessinian sources seem to be of some interest, especially prior to the establishment of the Galician manufactures around 1790.

Chelidonio (2006, 6) states that "*Austria was more or less cut off from the supply of gunflint workshops (with the exception of the workshops at Pian della Cenera, at the foothills of Avio/Monte Baldo, operated by the family Rudari[22] since 1775)*". Therefore, apart from the fact that non-documented smuggling of gun flint was common in the region, it appears that this was the only workshop region officially providing the Austrian army with gunflints in Lessinia at that time[23] (especially under unappreciated foreign control of the country, e.g., by the Bavarians or the French; Woodall & Chelidonio 2006, 216; Andreis & Chelidonio 2008, 163). The probably greatest production activities in the Lessini Mountains were concentrated around Cerro Veronese, Ceredo and S. Mauro di Saline, where at least some locals subsisted on gunflint production (Goldenberg 1999, 111-112; Woodall & Chelidonio 2006, 216).

Archaeological investigations concerning gunflint workshops in the Lessini Mountains conducted by Goldenberg (1999, 112) and Woodall (et al. 1997, 24-25), point in the direction of small scale and individual workshop patterns rather than industrialized organisation. Knapping sites were located next to stockpiles of local flint, accumulated by farmers for centuries in order to clear their pastures and agricultural fields. This and a local decree interdicting flintknapping in cultivated or occupied areas (Chelidonio 1991, 238; Goldenberg 1999, 112), is why the majority of workshops in the Lessini Mountains are found close to the field periphery and offside the villages (Goldenberg 1999, 112; Woodall et al. 1997, 17).[24]

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[22] "Rudari" see Appendix A, REF 30, footnote 54.
[23] At least until the French took control over the area. From 1806 on, smuggling was the only alternative.
[24] Remark G. Chelidonio: Recently we discovered several gunflint workshop traces situated in the upper part of the Lessini Mountains, historically devoted to summer pastures for sheep. These sites are located between 1200-

Raw material exploitation:

Apparently, two groups of people were engaged with the manufacturing of gunflints, local villagers and, in some provable cases, itinerant specialists employed by firms located in towns in the Adige Valley (e.g., Verona or Bolzano; Appendix A, REF 31, 384; Goldenberg 1999, 112; Woodall & Chelidonio 2006, 223-224). These people were called "*folendari*" (= flint workers). According to Benetti (Appendix A, REF 45), the *folendari* were separated into two categories, the *cataori* ("finders") and the *bataori* ("beaters" or "knappers"), who were specialized in the preparation of the rocks for gunflint production. The *cataori* were equipped with a wooden back frame with a shelf (*Krakesa*, note in german: *Kraxe*) for carrying the rocks, and a pick.

Historical reports (Appendix A, REF 7, 8 and 30, 31) confirm observations of rather individual activities concerning the gunflint manufacturing process in Lessinia, stating that the workmen avoided digging for the raw material (*selce* in italian, local term in Lessinia: *folenda*, or more frequently plural, *folende*; Chelidonio 1999, 7) and rather collected it from the surface if possible. If they had to dig, the pits were never elaborate and immediately backfilled after exploitation, never exceeding a depth of 1 Klafter (ca. 1,9 m). The only tool used for this activity was a combination of a hoe and a pick, the hoe for removing the top soil sediment and rubble, and the pick for testing the material.

Disagreements between the *cataori* and the owners of the alpine pastures additionally resulted in the infrequent exploitation of "various, widely scattered places", where only the top soil was removed to obtain the *folende*.

Gunflint Production:

Historical notes (Appendix A, REF 42-44, primarily REF 44) allow a reconstruction of the manufacturing process of gunflints at Avio, situated at the foothills of Monte Baldo.[25] Ployer (1800, REF 44) describes the following procedure:

1. After testing and sorting out suitable rocks, the workers squared the flint nodules at the site using the above mentioned hoe/pick.

1400 meters a.s.l., which makes us believe that gunflint production was also a part time summer activity of shepards.

[25] Remark G. Chelidonio: The pre-investigated Avio gunflint sites are located in a small valley called "Pian delle Cenere", at an elevation of ca. 1000 meter a.s.l.

2. This accomplished, the blades (*scaglie*) were also knapped at the exploitation site, in order to avoid carrying down useless weight. The tool used for this task was a hammer with a regular flat end and one pointed end.

3. The *scaglie* were then transported to the working places in the *Krakesa* (compare REF 45).

4. At the workplace, the blades were knapped into rectangular pieces. The tools consisted of a pin fit into a wooden block and a knapping bar, both from soft iron. The knapping was performed using the flat surface of the bar, but not the edge (which would eventually damage the work piece).

Benetti (Appendix A, REF 45) states: "When the working space was littered with knapping debris, the *bataor* took some of it and disposed it in crevasses of the limestone formations of the Rosso Ammonitico."

These workshops mainly produced rectangular shaped gunflints, also called "*Doppelsteine*" ("doubled stones"), for both, military and civilian purposes (Appendix A, REF 44).[26]

The results of the excavation campaigns conducted by Woodall & Chelidonio (2006, 224) in 1996 enabled them to distinguish characteristic patterns for the gunflint manufacture in the Lessini Mountains, which can be directly compared to the historical reports:

1. Distinctive tabular cores indicate a method of working the material adjusted to the size of the nodules and allow a reconstruction of the applied knapping method. Other that in Meusnes or Brandon, where the raw material allowed for the production of long blades yielding up to 5 gunflints, the typical Lessinian cores show the production of shorter blades, in most cases only allowing for obtaining one gunflint (compare REF 42 and 43).

2. Lenticular tertiary blades in combination with large and deep bulbar scars on the ventral side are characteristic, resulting from the use of a pointed metal percussor.

3. Linked to no.2, characteristic "shock impact-" marks occur, present at both platform margins and the heels of the blades. Oxidized iron traces, caused by the metal point of the hammer, are also commonly detectable.[27]

4. Blade segments typically bear a semi-cone, produced by direct percussion (either on the dorsal or on the ventral side). This feature occurs in the process of sectioning the lamellar blades into quadrangular pieces, the rough-outs for the gunflints.

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[26] Remark G. Chelidonio: So far, Verona gunflints were only knapped in the square style; very few gunflints of the French style – i.e. with roundish trimmed back – were found in Lessinian sites.
[27] Pers. comm. G. Chelidonio.

Economy:

According to Chelidonio (1999, 12), the earliest known document regarding gunflint production in the Lessini Mountains either dates to 1726 or 1766 (the date is not clearly legible), referring to the dowry of a certain Margherita Riva containing a stock of gunflints "made by Uncle Battista near Bà[28]". A notice from 1643, that "stones for firearms" were sold at Castel Tesino (Valsugana-Trento) could also be a reference to gunflint manufacturing in that region, however the mentioned "stones" might have been pyrites, garnets or the like (see Section 5.3.3.8.1. and Appendix A, REF 55).[29]

As indicated above, the first tangible reference to more frequent gunflint economy in Lessinia are the activities of the familiy Rudari around 1775. According to Andreis & Chelidonio (2008, 163), the gunflints produced in their workshops were distributed by entrepreneurs, as well as, via smuggling during politically and economically tense periods. The main transportation route led through the Adige Valley (compare REF 7 and REF 54), supplying the Habsburgian Lands.[30]

Andreis & Chelidonio (2008, 159) state that *"el Giorgio da la Montarina, () batèa folènde par i canòni"* and that *"el Salveti e le portàa in Austria co' le mule"* (Giorgio from Montarina stroke gunflints for the cannons and Salveti transported them to Austria, with mules). It is very likely, that "Signore Salvetti" was commissioned by the entrepreneur Luigi Boldrini, who operated a gunflint manufactory near Verona. According to Solinas (1953, 111), Boldrini exported "100 barrels of gunflints per day, containing 20,000 pieces each", during the Napoleonic Wars.[31] Chelidonio (2011, 49) determined by the lack of documents referring to *folendari* between 1805 and 1815, that the French possibly prohibited the production of gunflints during the time of the occupation of Lessinia[32] (which certainly does not rule out the possibility of "inofficial" continuation, supplying anti-French forces; the necessity of the concealment of such activities is a very probable reason for the scarcity of written documents during this particular period; Chelidonio 1999, 38). Immediately after the reintegration of the Lessinian territory into the Habsburgian Monarchy, statistics from 1816 list 500 workers for

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[28] A village ca. 12 km east of Ceredo.

[29] Remark G. Chelidonio: He is convinced, that pyrites for wheel-locks were sold in this area. There are two reasons for this assessment: 1.) the material is available in that region, and 2.) the early date (the flint-lock system was not common during the the XVII century).

[30] According to Binsteiner (1994, 257, footnote 10), the Austrian army ordered 1 million gunflints from Avio in 1775.

[31] The export of such a high amount of goods is barely imaginable by means of smuggling, and can therefore be dated to the time between 1797 and 1805 when Austria was in possession of at least parts of the Lessinia territory.

[32] This makes sense due to the fact that the French certainly had only little interest in the local gunflint industry in Lessinia, but wanted to block Austria's gunflint supplies.

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gunflint production in the Kingdom Lombardy-Veneto. An unpublished manuscript by Tommaso Bertoldi reveals that his grandfather was a *folendaro* during the same time period (1815-1859/66), inderdicted to produce "*folende*" for private business. Furthermore, the manuscript reveals that vendees came into Lessinia with mules from Trento, Ala and Rovereto, trading goods from Camposilvano and Rovereto for gunflints (Chelidonio 1999, 11-12).

The entrepreneur Gaettano Boldrini – descendent of Luigi Boldrini – complains in 1817, that commissioners from the Viennese Department of Artillery determined French gunflints to be cheaper and of better quality than his products, and that French gunflints were already conquering the entire (Austrian) Empire (Andreis & Chelidonio 2008, 160, 163 footnote 1). The reputation of Lessini gunflints appears to not have been the best since the beginning of their trading (compare REF 53, pg. 11-12; this report has to be treated with caution, because the author is advertising the gunflints from Burglengenfeld and excoriates the Lessinian products very emotionally. Nevertheless, he refers to the uselessness of those gunflints for military purposes in general. This is interesting in regard to the commissioner's judgement of Boldrini's gunflints; maybe they were only accepted as an emergency solution by the Austrian army, and dismissed after the Napoleonic Wars).

However, in 1837, Ferdinand I. from Austria passed through Verona and wanted to visit the gunflint manufacture of Luigi Boldrini. On that occasion, 22 "*folendari*" came from Cerro in order to demonstrate their knapping skills in presence of the Emperor (Chelidonio 1999, 8-9; Woodall & Chelidonio 2006, 216; Andreis & Chelidonio 2008, 163; Chelidonio 2011, 47). Boldrinis manufacture must have survived until the turn of the 20th century, because there is notice from 1886, that his firm was shipping gunflints from ports at the Adriatic Sea (Andreis & Chelidonio 2008, 161).

Chronological aspects:

Typical "Veronese" gunflints (*pietre focaie veronesi*) are rectangular shaped in the "English" style with two parallel edges, however they are generally thinner. In the Lessinia region, the advanced blade technology for platform type gunflint production was most likely adopted from the French during the late second half of the 18th century, indicated by a toolkit less

specialized than the French, but a very similar production process (see above and REF 44, pg. 160; Chelidonio 2003, 128).[33]

It seems likely, that the French *talon-rond* shape (ital. *„ferro cavallo"*, iron horse) was also introduced into the Lessinian manufactories during the time of French influence, by contact of the locals with French workers (Chelidonio 2010, 229). This incidence can be dated around 1796/97, coinciding with Napoleon's Italian Campaign. However, the horseshoe shape was not standard in Lessinian workshops, but a rather rare phenomenon (Chelidonio 1999, 38). According to Chelidonio (2010, 231), the production of "geometric" gunflints (standardized and knapped from blades) for military use was substantially reduced after 1815, and almost completely ceased after 1830. The reasons are primarily attributed to the end of the Napoleonic Wars (Andreis & Chelidonio 2008, 161), the inferior quality of the raw material (Chelidonio 1987, 122: ca. 1819; REF 53, pg. 11-12) and the high production costs (Emy 1978, 114). According to Paolo Orsi, at about 1885, *"pietre focaie veronese"* were only sent to Dalmatia, the Levante, the Tyrolean mountains and to Baviaria, predominantly for the use as strike-a-lights (Chelidonio 1999, 8-9).

5.3.3.8.3. Slovenia: Krain (ger.)/Carniola (engl.)

Historical reports mentioning chert and flint in Styria predominantly refer to the southern parts of the former Duchy of Styria and Carniola, now parts of Slovenia (Appendix A, REF 9 and 10).

Only two mineralogical publications provide more detailed information: Hatle (1885) mentions the "Laisberg at Cilli (*Lisce at Celje*) and Swetina south-east of the Dostberg", and Aigner (1907) refers to a substantial deposit of "blackish-brown coloured flint at Lichtenwald an der Save (*Sevnica*)" (Appendix A, REF 11 and 12). Nevertheless, no factual evidence for gunflint production in Slovenia is known to this point.

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[33] Remark G. Chelidonio: This is just a hypothesis, lacking documents so far; in the north-eastern part of Lessinia, a place was called *S. Mauro de Salino* in a document from 1765; since "salino" means acciarino ("firesteel") it is suggested that firestone production in Lessinia commenced much earlier, however not for flint-lock use.

5.3.3.8.4. Hungary

Emy (1978, 113) specifies sources of gunflints for the Austrian Empire, referring to "M. Maréchal, memoire du 16 messidor, an 7"[34] who claims that the Austrian army obtained this good "*de la Hongrie et du Tyrol italien près d'Avio, dans la vallée de l'Adige*" (from Hungary and Italian Tyrol at Avio, in the Adige valley).

REF 13 and 14 in Appendix A refer to "flint and jasper" from Hungary, however any industrial use is not specified.

Only Thiele (1833) mentions hills "delivering chert which is easily knappable and probably suitable for gunflint production" (Appendix A, REF 15). However, it is highly doubtable if there was any gunflint production established in Hungary (except for occasional short-termed attempts).

5.3.3.8.5. Austrian Silesia

Austrian Silesia, officially referred to as "Herzogtum Ober- und Niederschlesien", was a part of the countries under the Bohemian Crown within the Austrian Monarchy from 1804–1918. The historical reports concerning gunflint production in that part of the Empire are very scarce, and even extensive inquiries in the course of the present work only produced limited results.

Johann Adam Valentin Weigel, Lutheran preacher and natural scientist, gives a description of the natural resources of the Duchy Silesia (Appendix A, REF 17). He makes a distinction between chert and flint by visual appearance, mentioning yellowish chert at Tarnowiz (then located in the Landkreis Beuthen, nowadays Tarnowskie Góry in Poland), and flint "in small deposits" at Bobrowice (previously Boberwitz, Landkreis Sprottau/Silesia, the contemporary Szprotawa in Poland), without any reference to industrial use of the material.

There are only two historical sources directly referring to gunflint production in Austrian Silesia. Raymond et Roth (REF 18) mentions the production of gunflints of inferior quality in *Silésie Autrichienne* (Austrian Silesia).

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[34] An 7 = 1799 (according to the French Revolutionary Calender).

In his *"Versuch einer geognostischen Beschreibung von Oberschlesien und den nächst angrenzenden Gegenden von Polen, Galizien und östreichisch-Schlesien"*[35] from 1822, Carl von Dennhausen states: *"Flint gravels occur commonly there, specifically at Mackau[36] and Krawarn[37]; they have even been tested, however their occurrence was too scarce for establishing a flint factory."* (Appendix A, REF 19).

5.3.3.8.6. Polish territories of the Monarchy (Galicia)

Gunflint production in the former Polish possessions of the Austrian Empire is reported from Galicia (in the surroundings of Kraków), Pokutia (south-eastern part of Galicia, now Romanian-Ukrainian borderland), parts of Wolhynia (historical region in northwestern Ukraine), and Podolia (old name for a region comprising parts of southwestern Ukraine and northeastern Moldavia). These regions passed to the Habsburg Empire between 1772 and 1795 (Penz & Trnka 2004, 239).

It was mainly due to the endeavours of Balthasar Hacquet de la Motte (1739/40–1815), holding a professorship at Lemberg (Lviv), that a gunflint industry was established in the former Galician territories under Austrian control.

Workshops:

Balthasar Hacquet de la Motte, serving as a doctor and natural scientist with an emphasis on geology, visited and explored these remote areas focussing on economical aspects for the Monarchy. Encouraged by surveys concerning high quality SiO_2-material, he described seven varieties of flint, nodular and tabular, from the region around Kraków and an area between the rivers Dnjestr and Sbrucz in Podolia (*for a detailed description of workshops and raw material deposits see Appendix B*). Two of these varieties, both nodular, were best suitable for gunflint manufacturing, a yellowish-translucent type similar to the French material, but very scarce in Galicia, and a blackish variety known as "podolian flint" (Appendix A, REF 20; Penz & Trnka 2004, 239-240; Appendix B). The latter became of greater importance, and the quality of the flint was believed to even exceed the Meusnes flint. According to Hacquet, the

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[35] Attempt of a geognostic description of Upper Silesia and the bordering territories of Poland, Galicia and Austrian Silesia.

[36] Mackau: The village Makau/Maków in the Voivodship Silesia, Poland.

[37] Krawarn: Kravaře (Deutsch Krawarn), village in the region Moravian Silesia (Moravskoslezský kraj).

podolian flint was of greater "hardness", lasted therefore longer (up to 120 shots) and produced more sparks than the French material (Hacquet 1792, 60-61).

Main production sites were initially located at Brzezan (Brzeżany) and, after the transfer of the workshops to a region with a more favorable climate,[38] at Nizniow (Appendix B, 1.1. and 1.2.).

Raw material exploitation:

In Galicia, two source regions are of major importance for gunflint production (see Appendix B):

1) The surroundings of Kraków in western Galicia, south of the Vistula River (former governments (ger.: *Kreise*; pol.: *powiats*) Podgórze, Wieliczka und Bochnia). Investigations concerning gunflint production in contemporary Poland, conducted by G. Trnka in 2001 and 2011, produced several workshop- and quarrying sites in the hinterland of Kraków (e.g., Nizniow, Sąspów, Cajowice and Bębło). For comparison studies, samples from some of these sites were analysed.

2) The promontories of Podolia in the easternmost part of Galicia, between the rivers Dnjestr und Podhorce/Zbrucz (former Kreise Brzeczan, Stanislawowo, Podhajce, Zaleszczyk u.a.m.).

Due to the fact, that Galician flint was predominantly exploited from shallow residual deposits, quarrying did not require sophisticated mines with deep shafts like in England or in France (Appendix A, REF 32-34). Typically, the flint nodules were excavated during summertime by the peasant population and delivered to the factories. For quarrying, ordinary shovels, cramps and picks were used, digging up square pits to a maximum depth of 1-2 Klafter (ca. 2-3 m). Usually, the nodules were not processed on site, except for deposits remote from the factories, e.g., the Zapronci Mountains (Appendix B, 2.5.; Hacquet 1806/1, 98). The major disadvantage of the specific source conditions in Galicia was the relatively fast depletion of the shallow deposits, the consequence being that the entire infrastructure for gunflint production had to be transferred when the transport efforts exceeded the economic viability (Penz & Trnka 2004, 240).

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[38] Hacquet 1806/1, 98: *"…transferred to the mountains of Pokutia and UpperPodolia".*

Gunflint Production:

Initiated by Hacquet, the "French method" for gunflint production was applied in Galicia from the beginning. In 1789, Hacquet published a paper concerning the mode of production and the tools in use at *"Muene"* (Meusnes, France; Appendix A, REF 38). His main publication concerning gunflint manufacturing in Galicia was in essence a replication of his observations in France (Appendix A, REF 46). The production process and the applied tools are identical to those described in Section *5.3.3.5.2.1. France*, and will therefore not be recurred.

Archaeological evidence confirms the historical reports. According to Ginter (2009, 348-349), the *"classical example of gun-flint coming from mass production, in terms of both, standard parameters as well as the shape, is a horseshoe-shaped gunflint of thorough, regular, steep retouch and semi-steep, tiny retouch at the base, the latter one of evening character".* This gunflint type, produced conforming to the French military standard, was recognized at all significant sites in Poland (e.g., Zelków and Aleksandrowice).

Hacquet (Appendix A, REF 47) provides some information concerning division of labour practisced at the gunflint workshops. A higher remunerated *"Spalter"* ("splitter") kept up to 3-4 *"Zurichter"* ("processors") busy; the latter were usually boys between 12 and 14 years (compare Seel 1981, 1451-1452; Penz & Trnka 2004, 240)

Economy:

Based on the division of labour, the gunflint manufacturing process at Galician factories was very efficient, producing 1000-1500 pistol- and musket flints daily (Seel 1981, 1451-1452; Penz & Trnka 2004, 240). According to Hacquet (1792, 58), the Galician (Podolian) gunflints were exclusively produced for military purposes, however he refers to a total of 200,000 gunflints produced in the first year (1788), of which ca. 40–50,000 were rejected by the officials and sold for private use by the "Aerarium". In these early years, experts were sent to the production sites in order to train every countryman willing to earn some money on the side, in the art of gunflint knapping.

In 1809, Raymond et Roth (Appendix A, REF 21) states in his *"Tableau statistique de la monarchie autrichienne, au commencement de la guerre présente"* (Statistical tableau of the Austrian Monarchy, at the beginning of the present war), that "the fabrication of gunflints at

Brzecznan, in eastern Galicia, equips the entire army. In former times, they were imported from France..."

Hacquet's reports discuss the high quality of Podolian gunflints and in effect influenced the perception of subsequent authors in the promotion of Galacian products over the French (e.g., Hacquet 1792, 60-61; Appendix A, REF 57). Nevertheless, the general acceptance of Galician gunflints was not uncontradicted; Hohenhausen und Hochaus (Appendix A, REF 53) states, that "the (Poldolian) gunflints are not yet competitive" (to the French). The Podolian flint is considered "coarse, brittle, oversized, and does not allow precise knapping" (based on the investigation of several hundred thousand gunflints delivered from Austria to Bavaria).

Chronological aspects:

In the regions mentioned above (surroundings of Kraków, Pokutia, Wolhynia and Podolia), gunflint production commenced around 1787/88 as a result of Hacquet's investigations. The most productive period can be dated between the turn and the first half of the 19th century; the business was significantly restricted from 1850 on (see Appendix B, 1.2. Nizniow), merely supplying local demands for the use at hunting weapons and strike-a-lights. For the surroundings of Kraków, Ginter (2009, 350) assumes a continuation of *"mass flint production"* (mainly for private purposes and strike-a-lights) in particular workshops until 1880-1890.

5.3.3.8.7. Transylvania (Siebenbürgen)

Transylvania, under Austrian control since 1711, was transformed into Habsburgian Crown Land in 1765 (Ackerl & Kleindel 1994, 241).

Amongst other regions, Transylvania is frequently mentioned as a source for raw material suitable for gunflint production (Appendix A, REF 26 and 27). However, detailed descriptions are generally missing in these reports.

The only historical reference specifying possible gunflint production in Transylvania is provided by Hacquet's *"Physische und Technische Beschreibung der Flintensteine"* from 1792 (Appendix A, REF 25). He comments on "accumulations (*of flint nodules*) at

promontories, like in "*Valle Prodului, in Zarander Komitat*[39] *in Siebenbürgen.*" () According to Hacquet (1792), deposits in the "*Zarander und Hunyader Commitat in Siebenbürgen*" contain "cubically shaped flint", usable for gunflint knapping only to a very limited degree.

Investigations concerning Hacquet's "Valle Prodului" revealed the following information: "The areas with weak *(geomorphologic,* ed. Note*)* risk have low extension in north of Târnava Mare, presented under the form of patches in **Prodului**, Seleus (542 m) and Padurea Bisericii hills" (Costea 2007, 17). Further inquiries were impossible due to the author's ignorance to the Romanian language.

5.3.4. Raw material analysis

As indicated in the introduction to this chapter, the hope for conclusive assessments concerning the history of the Neugebäude cache was set on the investigation of the raw materials of the gunflints.

5.3.4.1. Schloss Neugebäude: Preliminary raw material determination

The spectrum of raw materials present in the Neugebäude assemblage shows a high diversity. For a preliminary determination, groups of visually similar material were defined **(see Table 5.3.1.)**. In 2003 and in 2004, J. Affolter conducted a microfacial investigation on 65 gunflints taking account of those predefined visual groups. The results are displayed in Table 1. According to Affolter, the majority of the raw material originates from French sources, dominated by flint from Meusnes (Dép. Loir-et-Cher, type varieties 139 and F-41; Affolter 2002, 98). Additionally, she identified flint from the Picardie region (e.g., Origny-Stainte-Benoîte) and from the Champagne-Ardennes area in the Vanne valley (e.g., Villemaur-sur-Vanne). From Northern Italy, greater parts of the assemblage were assigned to the Lessini Mountains and to sources at Monte Baldo (predominantly type variety 157 – Cerro Lessini; Affolter 2002, 128-129). Pieces of unknown origin show a microfossil fauna (bryozoa, foraminifera) comparable to inclusions characteristic for flint from the Baltic coast (Penz & Trnka 2004, 242-243).

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[39] Hungarian *Zaránd*, romanian *Zărand,* former hungarian Komitat, since 1870 part of the Arad and Hunyad Komitat. Today it belongs to Romania, kraj Arad.

J. Kopacz from the Archaeological Museum in Kraków additionally mentioned the possibility of Polish material from the Kraków region contained in the gunflint cache. Due to the high visual similarity of Meusnes flint and Jurassic Kraków "flint" (for a detailed description see *5.3.4.3.*), this idea had to be taken into consideration, especially since historical reports refer to gunflint industries in Galicia even exceeding the French production at their zenith (Hacquet 1792, 58-62; Seel 1978, 146; Slotta 1980, 352). Because Galicia was under Austrian control at the end of the 18th century (see Section *5.3.3.8.6. Polish territories of the Monarchy*), the identification of Polish material in the Neugebäude assemblage would have farreaching implications for the military history of Schloss Neugebäude at the turn of the 19th century.

Group no.	visually defined groups (Trnka & Penz 2004)	n	possible provenance (microfacial analysis Affolter 2003/2004)	geochemical analysis (Brandl & Hauzenberger 2011)
1	translucent "blond" flint	65	**France:** Meusnes, Villemaur-sur-Vanne; Charentes? *J. Kopacz: possibly jurassic Kraków "flint"*	7
2	translucent dark grey flint		**France:** Meusnes, Origny-Ste-Benoîte **Italy:** Monti Lessini, Monte Baldo *J. Kopacz: possibly jurassic Kraków "flint"*	
3	semitranslucent light grey spotted flint		**France:** Meusnes **Italy:** Monti Lessini *J. Kopacz: possibly jurassic Kraków "flint"*	5
4	semitranslucent grey flint with large speckles		**France:** Origny-Ste-Benoîte **Italy:** Monti Lessini	1
5	non translucent grey-beige flint		**France:** Meusnes **Italy:** Monti Lessini **Unknown origin:** Cretaceous flint (Baltic flint)	2

Table 5.3.1.: Preliminary raw material determination

Graph: M. Brandl.

5.3.4.2. Analytical Techniques

Specimens from the Schloss Neugebäude gunflint cache and representative raw material samples were visually, microscopically and petrographically/geochemically investigated according to the MLA as described in Chapter 4. This comparative study was conducted in order to validate the preliminary determination of raw materials contained in the gunflint cache from Schloss Neugebäude.

5.3.4.3. Raw materials from the comparative sources

Based on the preliminary investigations, samples from sources containing material visually similar to the archaeological finds were investigated. The source regions under discussion deliver SiO_2-varieties visually corresponding to the French material, the most demanded for gunflint production. Even the Lessini flint, although very characteristic in most cases, is considered undistinguishable from the French *"silex blond"* occasionally (Woodall & Chelidonio 2006, 225), and therefore included in this case study.

Comparative samples were provided by the Vienna Lithothec (VLI), Institute for Prehistory, University Vienna. Altogether, 133 samples were analysed, applying the MLA as described in Chapter 4.

According to the raw material proportions in the Neugebäude cache, the investigations focussed on sources potentially providing the main contingents: France, Poland and Italy. French material was investigated from the centre of gunflint production at Meusnes, Polish material from the vicinity of Kraków, and Italian flint from the Lessini Mountains **(Fig. 5.3.12.)**.

Fig. 5.3.12.: Location of the comparative sources/source regions

Adapted from Schweizer Weltatlas 2013

5.3.4.3.1. France (Meusnes)

Geographical setting

Meusnes is a little town situated in the Département Loir-et-Cher, Centre region, in the Loire Valley and ca. 2 km south of the river Cher. It is located on the terraces of the Cher River, at an altitude between 68 and 132 m a.s.l. **(Fig. 5.3.12.).**

Geological setting

Geologically, Meusnes and its hinterland are situated in the south-westernmost part of the Paris Basin (PB). The PB is an intercratonic[40] basin, framed by the Armorican Massif in the

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[40] Intercratonic = unaffected by massive fault processes caused by the continent's movement.

west, the Ardennes in the northeast, the Hunsrück and the Vosges in the east, the Morvan in the southeast and the Central Massif in the south. It developed during the Permian period, and was individualized before the Upper Trias. Sedimentation lasted until the Oligocene, and accumulated up to 3000 m of sediments. In the south-west, it was linked to the Aquitanian Basin, in the south to the Central Massif, and in the northwest it opened towards the English Channel (Brunet 1982, 8550).

The bedrock of the PB, dipping in western direction, consists of gneiss and granite.
In the course of the Jurassic period, marine transgression from the east covered the entire PB, depositing sand and sandy marls at the basin's rims, and limestones in the centre. Subsequently, a connection to the Aquitanian Basin and to the Atlantic sea was opened up, accumulating marly limestone and argillaceous shale. In the Dogger, the access to the Tethys-Ocean broke open; this connection remained stabile until the Lower Cretaceous stage, resulting in the aggregation of mainly limestone. Consequently, marls superseded by reef-limestone were deposited (Brunet 1982, 8552; Gräfe 1999, 44-45).

Local geology in the Département Loir-et-Cher (see Table 5.3.2.)
Cretaceous sedimentation appears relatively late at Loir-et-Cher, commencing at the beginning of the Turonien, and proceeding until the Campanian. The western part of the department developed various facies of flint bearing, loamy chalk, calcareous tuffs and sands, indicating continental proximity. The withdrawal of the ocean in the final stage of the Cretaceous period resulted in the shaping of the country's relief and alteration processes, such as the formation of the so called *"argiles à silex"*, the flint bearing clays.
In the Lower Eocene, the raising of the Central Massif caused the deposition of fluviatile, continental material; subsequently, shallow but large lacustrine lakes developed.
In Lower Miocene times, the ocean proceeded from the west, bringing in marine components again, but retired at the end of that period. During the Miocene, the Loire Valley was individualized. Large alluvial deposits (e.g., *Sables de Montreuil, Sables d'Herbault*) accumulated in the course of the withdrawal of the sea, and the rivers carved their initial channels and produced terraces through erosional processes until the beginning of the Quaternary stage. This period is also marked by the introduction of aeolian and fluviatile deposits, covering the plateaus of the north-western part of the department (Bouchut et al. 2004, 30).

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Petrographical description

According to Affolter (2002, 132), Meusnes flint can be petrographically described as follows:

RSS[41]:	Upper Turonian and Senonian formations.
Common names:	Meusnes flint; "Silex blond" (flintsource.net 2012).
Material:	Cretaceous flint.
Shape and size:	Nodules -20 cm diameter.
Cortex:	White, micritic; distinct boundary cortex – flint matrix.
Rock matrix:	Homogeneous, translucent-semi translucent, glossy on fresh fractures.
Structure:	Cryptocrystalline; Grain size according to ISO14688-1 (BSI 2009, 7): silt (fine-coarse).
Main constituents:	Cryptocrystalline quartz, radiolarians.
Facies:	Marine basin, shallow coastal region, poorly moved.
Genesis:	Flint nodules were formed in the course of diagenetic processes, affecting Turonian-Campanian chalk sediments.
Source of silica:	Cretaceous marine organisms (see *micropalaeontology*).
Non-fossil inclusions:	Pyrite crystals; sporadically geodes.

Micropalaeontology

Manivit et al. (1977) describe fossil inclusions from the genetic environments of Meusnes flint:

Upper Turonian: *Tuffeau de Touraine* (calcareous tuff of the Touraine).

Fossil inclusions: Bryozoa, serpules, echinoides and sponges remains (Manivit et al. (1977, 2-3).

Senonian: *Argiles à silex* (chert bearing clays).

Fossil inclusions: Globular sponges remains and spicula.

Lower Senonian: Rotaliform and valvulinid foraminifera, accompanied by bryozoa, spicula and sponges remains.

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[41] RSS = relevant stratigraphic sequences.

General: Affolter (2002, 132) conducted microscopical investigations on Meusnes flint and determined large bioclasts (e.g., molluscs, bryozoa, fish vertebrae), rarely foraminifers (Lower Cretaceous *hedbergellides*), dinoflagellates (planktonic organisms), as well as organisms of uncertain taxonomic position *(incertae sedis)*. Fossil inclusions were present at an average quantity of ca. 1%, ranging between 40-100 μm in size.

Analysis of the dinoflagellates revealed the following taxa: *Paleohystichophora infusorioides, Cleistosphaeridium huguoniottii, Phanerodinium setiferum, Spiniferites ramosus* (in samples from Vatan/La Foucaudiere, ca. 30 km SE of Meusnes), providing a chronological reference of the relevant geological formations to the end of the Turonian, at the turn of the Coniacian stage.

Archaeological evidence

Flint for gunflint production was not only quarried at Meusnes, but in the vicinity of several villages in the Cher Valley (e.g., St. Aignan, Couffy, Valençay, Lye). However, for the present study we focus on the Meusnes area, famous for the extraction of the typical Berry flint, also referred to as *"silex blond"*. The quarrying activities at Meusnes mainly took place on the hills south of the town, roughly confined by the roads D 33-Le Moulin Vernail in the west and D 956-Route de Valançay in the east, and at the level of the village Les Moreaux in the south **(Fig. 5.3.13.).** The mining area covered an area of approximately 5,5 km^2. Gunflint workshops were located in and around Meusnes, with Porcherioux as one of the main manufacturing places, especially in the later history of gunflint production (Schleicher 1931, 452).

Sampled site

Meusnes-Le Quartier

In August 2004, G. Trnka had the opportunity to participate in the excavation of a mining shaft at Meusnes-Le Quartier, in the Bois Pontois area (vineyard of Jacky Preys). Samples were chosen from the original backfill of the shaft, illustrating a representative selection of the *"silex blond"* type variety.
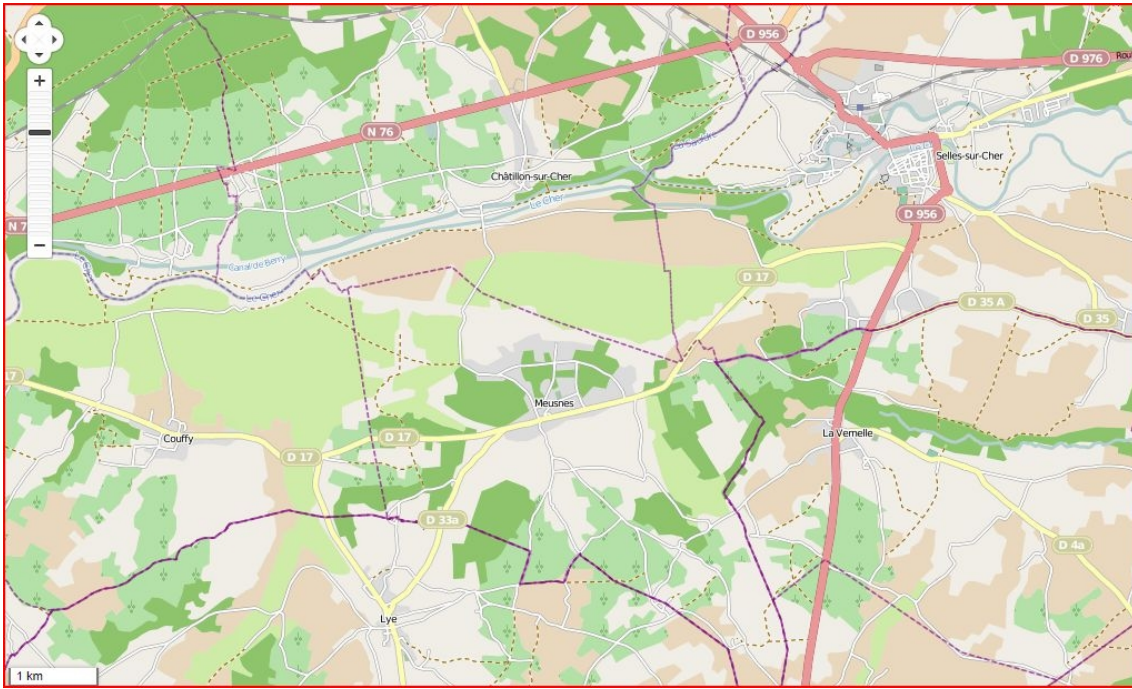
Fig. 5.3.13.: Location of Meusnes

Source: OpenStreetMap.

5.3.4.3.2. Poland (Kraków vicinity)

Geographical setting

The area of interest for this case study, the hinterland of Kraków, is situated in the Voivodship Lesser Poland, Powiat Krakowski, in southern Poland **(Fig. 5.3.12.).**

In terms of geology, the region is commonly referred to as "Kraków-Częstochowa Upland". This particular geological zone is part of the Kraków-Wieluń Upland, a section ca. 160 km long and 20 km wide. The landscape is dominated by rolling hills of approximately 100 m elevation and the adjacent valleys, famous for its carbonate rocks towers, cliffs and monadnocks.

From the northwest to the southeast, exposures of Jurassic limestone extend from the town of Wieluń to the city of Kraków. The southernmost part of the Kraków-Wieluń Upland, the Kraków Upland, is characterized by low hills, rising up to 500 m a.s.l., and deep valleys cut into the plateau.

Geological setting

The Kraków-Wieluń Upland is part of the larger Silesian-Kraków Monocline, comprised of (locally restricted) Triassic, Jurassic and Cretaceous sediments. They overlay the bedrock of the Palaeozoic European Platform. The development of the Silesian-Kraków Monocline commenced in the Early Cimmerian orogenic[42] phase, and fully developed during the Cretaceous Laramide orogeny as wells as in the course of Miocene deformations (Matyszkiewicz 2008, 649-650).

The area of the Kraków Upland was originally a basin situated in the southernmost part of the epicontinental Peri-Tethyan Sea, connected to the northernmost shelf of the Tethys during the Oxfordian stage (Fraaije et al. 2012, 648).

The model of the development of the Upper Jurassic sedimentary basin in South Poland is based on the assumption, that massive limestone accumulations formed submarine ridges and elevations surrounded by depressions, where the chert bearing bedded limestones were deposited (Alexandrowicz & Alexandrowicz 2003, 44).

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[42] Orogeny: Mountain-forming faulting and overthrust processes.

In this basin, Upper Jurassic sedimentary rocks immediately overlay the Palaeozoic basement, or, in rarer cases, Triassic and/or Middle Jurassic layers. The Upper Jurassic sediments are of Oxfordian and Lower Kimmeridgian age, subdivided into a so called massive and a bedded facies. In the vicinity of Kraków, the massive facies is interlocked with the overlying bedded facies (Matyszkiewicz 2008, 649-650). The massive facies is in most cases chert-free.

The bedded facies is comprised of a mighty series of alternating marls and marly, platy limestone (chert-free) of the Lower Oxfordian and the lower part of the Middle Oxfordian. Some publications refer to those layers as Jasna Góra Beds. The late Middle- and Upper Oxfordian as well as the Middle Kimmeridgian sediments are highly diverse in their manifestation. In the Kraków Upland, the bedded facies is characterized by platy limestones, intercalated by thin marly layers. Middle and Upper Oxfordian layers are developed as thick-bedded, sponge-microbial limestone typical of the northern shelf of the Tethys, bearing an abundance of chert nodules (Matyszkiewicz 2008, 649-650). In the course of alteration, residual deposits were formed in the uppermost components of the bedded facies, containing the resistant chert nodules in a clayey matrix.

Petrographical description

Kaczanowska & Kozłowski (1976, 215-216) defined 6 varieties of "proper Jurassic flint", and three cretaceous varieties, based on the thickness of the cortex, the boundary between cortex and rock matrix, the coloration, transparency and precipitations of the latter, as well as the shape and size of the nodules. Raw material suitable for gunflint production correlates with type variety A from that compilation:

Cortex: Thick–average, rough, consisting of silica-saturated limestone. Distinct boundary zone between cortex and rock matrix.

Matrix: Light brown-dark brown coloured, SiO_2-precipitations can occur.

Occurrence: Abundant in Jurassic rock formations of Southern Poland.

Mainly following Matyszkiewicz (1989) and Migaszewski et al. (2006), this particular raw material shows the following characteristics:

RSS:	Mid Upper Oxfordian-Lower Kimmeridgian formations.
Common names:	In archaeological literature often referred to as "Jurassic flint from the Kraków-Częstochowa Upland"; "Kraków flint"; "Polish Jurassic flint" (e.g., Kaczanowska & Kozłowski 1976, 215; Kaczanowska et al. 1979, 179; Lech 1980a, 228; Pawlikowski 1993, 74; Kadrow 1995, 242-243; Pelisiak 2006, 73-74; Sitlivy et al. 2008, 57; flintsource.net 2012).
Material:	Jurassic chert.
Shape and size:	Nodules – sometimes flattened – mainly up to 15 cm diameter; rarer up to 20 cm.
Cortex:	White-sand yellow, calcareous; definite boundary cortex-flint matrix.
Rock matrix:	Homogeneous, translucent-semi translucent, glossy on fresh fractures.
Structure:	Crypto-microcrystalline; Grain size according to ISO14688-1 (BSI 2009, 7): silt (fine-coarse) – fine sand.
Main constituents:	Cryptocrystalline and subordinate microcrystalline quartz, sponges remains (Migaszewski et al. 2006, 27). According to Senowbari-Daryan et al. (2008, 186), microbialites are the principal rockforming components of chert nodules from the bedded facies.
Facies:	Shallow water, emergent fragments of the basin's floor; low energy environment, sporadically occurring intense water movements. Upper Jurassic sediments of the Kraków-Wieluń Upland are part of the microbial megafacies, a belt stretching along the northern shelf of the Tethys Ocean (Senowbari-Daryan et al. 2008, 186).
Genesis:	According to Matysziewicz (1989, 218-219), chert formation processes commenced in the early diagenetic stage of the bedded limestone sequence. Chert horizons were predominantly formed in areas showing elevated clay contents, linked to synsedimentary stratification surfaces. Based on the low crystallinity index of the SiO_2, Migaszewski et al. (2006, 25) suggest a rapid precipitation from a silica-rich solution and subsequent diagenetic conversion of opaline sponges spicula to cryptoquartz.
Source of silica:	Matysziewicz (1989, 218) proposes sponges as predominant sources of silica, admitting, that their *"siliceous skeleton only constitutes less that ten percent of their weight."*

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On that account, Migaszewski et al. (2006, 26) suggest hydrothermal activity (hot springs on the sea bottom, emitting silica-enriched solutions) as an alternative Si-source.

Non-fossil inclusions: Intraclasts (rounded fragments of earlier lithified sediment, up to 1 mm diameter); geodes; peloids (micritic grains -0,2 mm diameter, most common constituents of bedded and massive facies), tuberoids, ooids (0,1-0,3 mm diameter; Kaczanowska et al. 1979, 183; Lech 1980a, 211; Matysziewicz 1989, 210).

Micropalaeontology

The Upper Oxfordian sponge microbial bedded limestone facies shows typical elements of a sponge megafacies limestone (Fraaje et al. 2012, 648).

Matysziewicz, J. (1989, 206-210) gives notice of the following microfossil inclusions:
Sponges, on their lower surfaces settled by epifauna, mainly bryozoans and polychaetes;
According to Lech (1980a, 212), sponges remains in Kraków "flint" typically show significant associations with forams, and – rarer – radiolarians.
Foraminifers; in bedded limestone, the most numerous families are Nodosaridae; Spirillinidae and Nubeculariide are underrepresented.
Brachiopods, bryozoans, echinoderms (predominantly crinoids segments, sea urchins spines), polychaetes (serpules), and rarely ostracods (compare Krajewski 2001, 45).

Archaeological evidence

The sites of raw material extraction for gunflint manufacturing in that region are located in a radius of no more than 20 km around Kraków (Matyszkiewicz 2008, 647), however it is not possible to reconstruct the extension of the mining district at the present state of research. The gunflint workshops were partly concentrated in nearby towns (see Appendix B) and partly scattered over the landscape, in very close proximity of the outcrops.

Sampled sites

Four sites were chosen for comparison of the "Galician" raw material. References to those sites are provided by Ginter & Kowalski (1964), and Lech (2008). G. Trnka conducted surveys in the area around Kraków in 2000 and again in 2011, providing the raw material samples.

Mników

This little village is situated ca. 15 km west of Kraków, on the Kraków Upland. The sampled site is located ca. 2 km NW from Mników in tributary valley of the Dolina Mnikówska, part of the Tenczyński reserve **(Fig. 5.3.14.).**

The tree-covered site revealed dense accumulations of knapping debris (core preparation), in the context with apparent quarrying pits **(Fig. 5.3.14.)**. Krzeszowice (see Appendix B, 1.4.), one of the places historical sources refer to as a gunflint manufacturing site, is only 9 km to the NW of the sampled area.

Bębło

Located ca. 18 km NW of Kraków, and ca. 12 km E-NE of Krzeszowice **(Fig. 5.3.14.)**, this site delivers abundant raw material from surface deposits. Although no historical quarrying and/or core production for gunflint manufacturing is known from Bębło, there are numerous finds of prehistoric artifacts in this area. The samples were collected from heaps of Kraków "flint" at a location called Kolonia Południowe, accumulated by farmers at the field peripheries over the years.

Czajowice

Czajowice is situated only 2 km NE of Bębło (17,5 NW of Kraków, **Fig. 5.3.14.**), and generally shows comparable conditions to those at Bębło. Raw material deposits occur very close to the surface and contain typical Upper Jurassic Kraków "flint". The samples were collected from agricultural fields.

Sąspów

The Sąspów – site is located ca. 4,5 km NE of Czajowice and 22 km NE of Kraków **(Fig. 5.3.14.).** Although there exists no documentation concerning gunflint production, the site is an important Neolithic quarrying area due to its early radiocarbon dating (LBK and Lengyel-

Polgár). Several excavation campaigns revealed a mining area with shafts and adjacent lithic workshops (Lech 1980b; 1980c). The raw material is typical Kraków "flint".

Presently, development has overtaken the site, almost entirely erasing the traces of the mining field. Samples were collected in the year 2000 at a crossroad where surface material was accumulated.
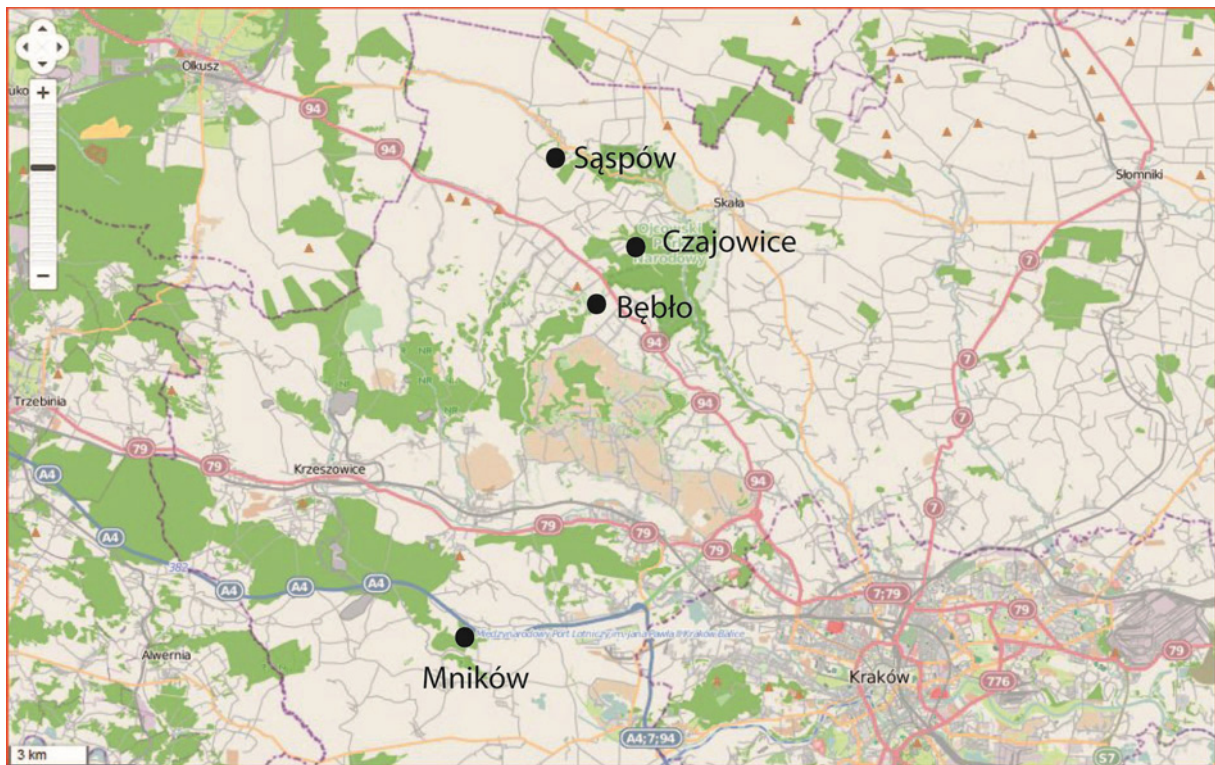

Fig. 5.3.14.: Location of the sources in the Kraków region

Source: OpenStreetMap.

5.3.4.3.3. Italy (Lessinia)

Geographical setting

As indicated in Section *5.3.3.8.2. Italy*, Monte Baldo and the Lessini Mountains are located on the right side of Lake Garda *(Lago di Garda)* in the hinterland of Verona, in northern Italy. In a greater context, Monte Baldo and the Lessini Mountains are situated in the south-easternmost part of the Southern (Calcareous) Alps **(Fig. 5.3.12.)**.

Monte Baldo, a mountain range of ca. 30 km in length, is situated between the Garda Lake and the Adige Valley *(Valle dell'Adige)*, with several peaks reaching an elevation of 2200 m a.s.l. max. Physiographic, MB belongs to the Garda Lake Mountains *(Prealpi Gardesane)*, confined by the Po Valley in the south, the Brenta group in the north, the Valle Giudicarie in the west and the Adige Valley in the east.

The Lessini Mountains, a roughly triangular shaped rock mass constituting the southern rim of the Alps, are located between the Adige Valley and the Valle del Leogra. The mountains raise to an elevation of ca. 1800 m a.s.l. in the north, declining towards the south. The Monti Lessini are a component of the Vicentine Alps *(Prealpi Vicentine)*. Adjoining the Adige Valley in the west, the Vicentine Alps extend to the Fersen Valley and the Val Sugana in the east, the Po Valley in the south and the Fleimstaler Alps in the north.

Geological setting

Geologically, the Alps are divided into three tectonic main units: The Western Alps, the Eastern Alps (containing the NCA) and the Southern Alps, the latter characterized by their southern vergence and low alpine metamorphosis. The delimiting element of the southern alpine complex towards the other units is the fault system of the neogene periadriatic line (Gail Valley, Puster Valley, Judicarian, Insubric, Valtellina and Canavese line). The Southern Alps, extending ca. 600 km in east-western direction and ca. 75 km wide, were in their substantial parts formed during the Lower Carbon.

In the eastern part of the Southern (Calcareous) Alps – the area Monte Baldo and the Lessini Mountains are situated in – rock units are comprised of marine sediments and delta debris (molasse). Their deposition commenced in the Westfalian and Lower Permian stage (Palaeozoic), unconformable overlaying the metamorphous basement. During the Triassic period, a typical carbonatic platform was formed from marine sediments, superseded by volcanic rocks, indicating the break-up of the Pangean crust in the Middle Trias (Cotza 2009, 10).

According to Binsteiner (1994, 255-257) and Bertola (2011, 464-465), the eastern part of the Southern Alps shows a relatively uniform setting in Jurassic and Cretaceous times. The geological layers are constituent parts of the Trento Shelf, a submarine elevation in the Jurassic and Cretaceous Tethys Ocean. The area under discussion was located on the NW margin of this submarine ridge. The rock units in that area are mainly comprised of limestone sequences, some of which are chert bearing. In detail, these stratigraphic members are the Jurassic *Calcari Oolitici di S. Vigilio* and *Rosso ammonitico veronese* series, together reaching a thickness of 100– 00 m. They are overlayed by the Upper Jurassic/Lower Cretaceous Biancone limestone (comprised of carbonatic mud) and the Cretaceous Scaglia rossa (together up to 400 m thick), deposited under pelagic conditions in the course of the drop of the CCD. This situation lasted until the Late Cretaceous. The rock series linked to these sedimentation processes show a slight decline, mainly in western direction. Post-depositional karst formation processes, affecting the Jurassic and Cretaceous limestone, lead to secondary accumulation of the resistant SiO_2-rocks in residual weathering loam deposits.

Petrographical description

Best descriptions concerning flint from the Lessini Mountains are provided by Binsteiner (1994) and Bertola (2011):

RSS: Mid Upper Oxfordian-Lower Kimmeridgian formations.
Common names: Lessini flint; Verona flint; Biancone flint (flintsource.net 2012).
Material: Lower Cretaceous flint.
Shape and size: Roundish-oval shaped nodules up to 25 cm diameter.
Cortex: White, micritic; blurred boundary cortex-flint matrix.

Rock matrix:	Homogeneous, rarely translucent, frequently semi translucent-non translucent, glossy on fresh fractures.
Structure:	Cryptocrystalline;
	Grain size according to ISO14688-1 (BSI 2009, 7): silt (fine-coarse).
Main constituents:	Cryptocrystalline quartz, marine fossil inclusions (see *micropalaeontology*).
Facies:	Marine pelagic environment; transition zone shallow water–open sea, succeeding the opening of the North Atlantic and the linked Ligurian Ocean (Bertola 2011, 464).
Genesis:	Flint was formed in the course of diagenetic processes affecting Biancone sediments (dense, thick-layered micritic limestone).
Source of silica:	Biogenic, dissolution of siliceous plankton and siliceous sponges (Bertola 2011, 466).
Non-fossil inclusions:	Frequently irregularly shaped intraclasts, occasionally geodes.

Micropalaeontology

Binsteiner (1994) describes a distinct microfauna included in flint from the investigation area:

Monte Baldo:
Crinoidea, bioclasts, and rarely radiolarians (Binsteiner 1994, 259).

Ceredo:
Sponges remains, crinoidea, bioclasts, shell remains, spicula (triactine and tetractine), echinoderms, rarer radiolarians. No foraminifers were detected.
The tetractine spicula are considered characteristic elements of the grey flint from Ceredo (Binsteiner 1994, 260).

Bertola (2011, 466) additionally mentions diatoms and silicoflagellates as important fossil inclusions in Biancone flint.

Archaeological evidence

Raw material for gunflint production was in most cases collected from surface deposits, or quarried from residual deposits (see Section 5.3.3.8.2). Workshops, mostly in close vicinity of the deposits, are known from several sites on Monte Baldo and the Lessini Mountains, however the most extensive activities are recorded from Cerro Veronese (central Lessinia), Ceredo (central western Lessinia) and S. Mauro di Saline (central Lessinia, east of Cerro Veronese). The Pian della Cenere site is located in the northern central section of Monte Baldo, above Avio, at an elevation of ca. 1000 m a.s.l.

Sampled sites

Two sites were selected for the comparison study, both containing material visually similar to the raw material of gunflints assigned to the Lessinia source region.

Ceredo
Ceredo is located on a ridge in the western central part of the Lessini Mountains, ca. 20 km north of Verona, at an elevation of ca. 800 m a.s.l. **(Fig. 5.3.15.)**. Residual loams contain huge amounts of Biancone-flint, which was quarried for gunflint production; quarrying pits are still preserved on a slope above the connecting street (SP 34c) between Ceredo and the village Fosse (Binsteiner 1994, 257).
G. Trnka visited Ceredo in 2002 (accompanied by G. Chelidonio) and collected samples from a recent outcrop of Biancone flint in residual loam, exposed by house construction activities.

Sant'Anna d'Alfaedo
Situated only 2 km west of Ceredo, primary flint bearing Biancone limestone strata are exposed at Sant'Anna. One of these outcrops was sampled in 2002 at the locale *"Dosso Morandin",* accessible due to road construction **(Fig. 5.3.15.)**.

Fig. 5.3.15.: Location of the sources in the Lessinia area

Source: OpenStreetMap.

Period	Epoch	Stage		Meusnes	Kraków	Lessinia
Holocene				Modern and recent alluvial deposits		karst formation processes
Neogene				Éocène détritique continental		
Paleogene				Alluvial sand and gravel deposits from the Cher river	In some areas Cretaceous and Miocene sand and gravel deposits; otherwise altered residual deposits of the bedded facies	Scaglia rossa
Cretaceous	Late (Upper)	Maastrichtian	Senonian[43]	**Various Upper Cretaceous Flint bearing formations; *"argiles à silex"***		
		Campanian				
		Santonian				
		Coniacian				
		Turonian		**Upper Turonian: Tuffeau de Touraine**		
	Early (Lower)	Cenomanian		Pre-Turonian marine sediments (sand, sandy marls and limestone)		**Biancone**
		Albian				
		Aptian				
		Barremian				
		Hauterivian				
		Valanginian				
		Berriasian				
Jurassic	Late (Upper)	Tithonian				Rosso ammonitico veronese
		Kimmeridgian			**Lower Kimmeridgian: bedded facies**	
		Oxfordian			**Middle and Upper Oxfordian: Bedded facies** **Early Oxfordian: Massive facies**	

Table 5.3.2.: Stratigraphic position of the chert/flint bearing

formations of the comparative sources (sections highlighted in bold)

Table adopted from Olivero 2003, fig. 1.

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[43] Senonian: Local divisoin used in France and Belgium.

5.3.4.4. Gunflints from Schloß Neugebäude

5.3.4.4.1 Sample description

For the present study, 15 gunflints from the Schloss Neugebäude cache were investigated. In the course of preliminary studies, ten specimens were visually suspected to origin either from France or from Poland, and five were pre-determined as Lessini flint.

Macroscopical description

As far as possible, the visual description follows the predefined visual groups and Affolter's microfacies investigations in **Table 5.3.1**.

Suggested origin: Meusnes
Five gunflints assigned to the Meusnes region (samples 234-238) show a yellowish-brown to light grey colour range. According to the definition in Chapter 4, three specimens are translucent, and two are semi-translucent; three pieces show infrequently distributed large, white speckles in the rock matrix **(Table 5.3.3.)**.
These assessments roughly correspond to the groups No. 1-3 in **Table 5.3.1.**

Suggested origin: Kraków
The five specimens suspected to be of Polish origin (samples 244-248) are very similar to the ones assigned to Meusnes. However, two show a slightly different appearance, sample 245 (darker in colour) and sample 247 (spotted). In this group, three gunflints are again translucent and two semi-translucent. Only samples No. 246 and 247 contain frequently interspersed speckles in the rock matrix **(Table 5.3.3.)**.
According to **Table 5.3.1.**, these gunflints show an approximate correspondance to the groups No. 1-3.

Suggested origin: Lessinia

These gunflints (samples 239-243) show a consistently different appearance than those of the first two groups. The colour of the specimens exhibits a larger diversity, ranging from yellowish-brown to dark grey. All samples contain great amounts of characteristic white speckles of various sizes **(Table 5.3.3.).**

Three significant macroscopic groups were detected at the investigated gunflints:

1.) "Flesh-coloured" slightly reddish-pink (sample 239); possible source regions: Monte Baldo, Monti Lessini (e.g., Ceredo, containing a very broad colour spectrum, ranging from honey-yellow, "flesh-coulured", over brown to almost black; Binsteiner 1994, 260).

2.) Yellow (samples 240, 241); possible source region: Monti Lessini (e.g., Ceredo)

3.) Grey (samples 242, 243); possible source region: Monti Lessini (e.g., Ceredo)

Such raw material varieties can be nearly correlated with the groups No. 2-5 as indicated in **Table 5.3.1.**

Microscopical description

All gunflints are characterized by a cryptocrystalline texture, high homogeneity, and the absence of any kind of fissures, thus providing excellent knapping properties. A detailed sample description is provided in **Table 5.3.3.**

When present, microfossil inclusions provide possibilities for source distinction due to different genesis environments and ages of the geological formations containing the comparative raw material deposits. The potential for a determination depends on multiple factors, e.g., the preservation of the included fossils. As mentioned above, not all specimens contain characteristic fossil inclusions, making the assignment even more problematic (e.g., sample No. 248; compare **Table 5.3.3.**).

suggested provenance according to table 5.3.1.	sample no.	munsell colour	inclusions	inclusion size	
				max µm	min µm
Meusnes	234	10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown (t.); sparsley large white speckles	Few large intraclasts, few SiO_2-precipitations, geodes filling hollow spaces of dissolved fossil inclusions, polygonal intact sponge skeleton, echinoderm spine fragment, unidentified fossil remains, marine detritus	500	50
	235	10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown (t.)	Few SiO_2-precipitations, echinoderm remains, few spicula, marine detritus, unidentified fossil remains	1000	90
	236	10YR 6/6 dark yellowish orange - 10YR 5/4 moderate yellowish brown (t.); white patches	Massive intraclasts, SiO_2-precipitations, sponge remains, few spicula, marine detritus, unidentified fossil remains	600	50
	237	10YR 6/2 pale yellowish brown with inclusions of 10YR 6/6 dark yellowish orange (s.t.)	SiO_2-precipitations (massive), few spicula, scattered radiolarians, few echinoderm remains, marine detritus, unidentified fossil remains	800	50
	238	10YR 6/2 pale yellowish brown - 5Y 7/2 yellowish gray (s.t.); sparsley large white speckles	Few intraclasts, SiO_2-precipitations, spicula, sponge remains, marine detritus, unidentified fossil remains	1000	50
Kraków region	244	10YR 5/4 moderate yellowish brown (t.); sparsley white speckles	Intraclasts, SiO_2-precipitations, few spicula, sponge remains, 1 large inclusion (dissolved echinoderm spine?), marine detritus, unidentified fossil remains	1500	50
	245	10YR 4/2 dark yellowish brown (t.)	Echinoderm spine fragment, sponge remains, spicula, massive marine detritus, unidentified fossil remains	1100	50
	246	10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown (s.t.); frequently white speckles	Intraclasts, SiO_2-precipitations, spicula, sponge remains, scattered echinoderm spine fragments, massive marine detritus and unidentified fossil remains	2500	50
	247	10YR 5/4 moderate yellowish brown (spotted, s.t.); frequently white speckles	Intraclasts, SiO_2-precipitations, partly massive spicula (multiaxial), sponge remains, few echinoderm spine fragments, massive marine detritus and unidentified fossil remains	500	50
	248	10YR 5/4 moderate yellowish brown - 10YR 6/6 dark yellowish orange (t.); very few white speckles	Few intraclasts, few spicula, few marine detritus and unidentified fossil remains; 1 unidentified "brench" structure; generally poor in inclusions	7000	50

suggested provenance according to table 5.3.1.	sample no.	munsell colour	inclusions	inclusion size max µm	inclusion size min µm
Lessinia	239	5YR 7/2 grayish orange pink - 10YR 6/2 pale yellowish brown (s.t.); many white speckles of various size	SiO_2-precipitations, intraclasts, radiolarians -15% content, few monaxon spicula, marine detritus	100	30
	240	10YR 6/2 pale yellowish brown (s.t.); many white speckles of various size	SiO_2-precipitations, intraclasts, radiolarians -10% content, few monaxon spicula, marine detritus	100	50
	241	10YR 5/4 moderate yellowish brown (n.t.); many white speckles of various size	SiO_2-precipitations, intraclasts, radiolarians -30% content, monaxon spicula, marine detritus, massive unidentifyable fossil inclusions	500	50
	242	N6 medium light gray - N5 medium gray (n.t.); many white speckles of various size	SiO_2-precipitations, intraclasts, radiolarians -50% content, spicula (monaxon, triactine, tetractine), trochites (?), marine detritus, massive unidentifyable fossil inclusions	600	50
	243	N4 medium dark gray - N3 dark gray (n.t.); many white speckles of various size	SiO_2-precipitations, intra, radiolarians -50%, few spicula, mar det, massive unidentifyable foss incl	200	50

Table 5.3.3.: Description of the sampled gunflints from Schloss Neugebäude

Key: n.t. = non translucent; t = translucent; s.t. = semi-translucent

Graph: M. Brandl.

Surface alterations

Distinguished from prehistoric lithics, the Neugebäude gunflints were subjected to depositional processes only to a limited extent. Nevertheless, surface alterations influencing the geochemical composition of the rocks have to be taken into consideration since the cache was buried, and possibly got in contact with impregnating substances deriving from the industrial activities (e.g., gunpowder and saltpeter production) at the area of Schloss Neugebäude.

5.3.5. Results

5.3.5.1. Characterization of the geological sources

5.3.5.1.1. Macroscopical investigations

All specimens except for some coarse grained samples from the Kraków Upland are characterized by a high homogeneity and a glossy shine on the fractured surface. Characteristics of raw material from the comparative sources are displayed in **Table 5.3.4.** Both, Meusnes flint and Lessini material bear typical white intraclasts, and fossil inclusions are commonly visible by naked eye in Kraków chert. However, distinctions are in some cases difficult due to similarities occurring within the range of raw material varieties contained in the deposits. Especially Meusnes and Kraków raw materials are visually very alike and macroscopically not well distinguishable. MLAS 2 and 3 are imperative for a differentiation (compare **Table 5.3.4.**).

source		munsell colour of the investigated samples	visual characteristics
Meusnes	Meusnes-Le-Quartier	10YR 6/6 dark yellowish orange - 10YR 5/4 moderate yellowish brown - 10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown (t.); white patches. Cortex: N9 white - 5Y 8/1 yellowish gray	rarely cleft, shiny gloss on fractured surface, irregularly shaped white intraclasts
Kraków	Bębło	10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown - 10YR 6/2 pale yellowish brown - N8 very light gray - N7 light gray (s.t.). Cortex: 10YR 7/4 grayish orange	rarely cleft, shiny gloss on fractured surface, rarely grey-white intraclasts; frequently godes; microfossil inclusions macroscopically visible
	Mników	10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown (t.) - 5YR 5/2 pale brown (t.) - 5YR 4/1 brownish gray (s.t.). Cortex: 10YR 7/4 grayish orange	
	Czajowice	10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown (t.) - 5YR 5/2 pale brown (t.) - 5YR 4/1 brownish gray (s.t.). Cortex: 10YR 7/4 grayish orange	
	Sąspów	10YR 5/4 moderate yellowish brown - 10YR 4/2 dark yellowish brown - 10YR 6/2 pale yellowish brown - 5YR 5/2 pale brown (t.) - 5YR 4/1 brownish gray (s.t.) - N8 very light gray - N7 light gray (s.t.). Cortex: 10YR 7/4 grayish orange	
Lessinia	Ceredo grey	N7 light gray - N6 medium light gray - N5 medium gray - N4 medium dark gray - N3 dark gray (n.t.); many white speckles of various size. Cortex: 10YR 7/4 grayish orange	often heavily cleft, shiny gloss on the fractured surface, frequently great amounts of irregularly shaped white intraclasts of varous sizes
	Cerdeo yellow	10YR 7/4 grayish orange - 10YR 6/2 pale yellowish brown - 10YR 5/4 moderate yellowish brown (s.t. - n.t.); many white speckles of various size. Cortex: 10YR 7/4 grayish orange	
	St. Anna D'Alfaedo	5YR 7/2 grayish orange pink - 5YR 5/2 pale brown - 10R 6/2 pale red - 10YR 6/2 pale yellowish brown (s.t.); many white speckles of various size. Cortex: 10YR 7/4 grayish orange	

Table 5.3.4.: Visual properties of the comparative samples

Graph: M. Brandl.

5.3.5.1.2. Microscopical investigations (see Fig. 5.3.16. and Table 5.3.5.)

All investigated comparative samples show a cryptocrystalline texture, Kraków material can additionally be of microcrystalline constitution.

Microscopical analysis of representative samples from Meusnes revealed radiolarians as the main constituents of the material, which are completely dissolved in the core parts of the flint but occasionally well preserved at the transitional zone between the cortex and the rock matrix **(Fig. 5.3.16. a and f -g: part of a radiolarian skeleton)**. Determinable fossil remains in the flint matrix are predominantly remains of echinoderms (e.g., sea urchins; see **Fig. 5.3.16. c-e: e - spine part, and d - skeleton**) and sponge remains (mainly monaxon spicula; **Fig. 5.3.16. b)**. Dinoflagellates, as described by Affolter (2002, 132), are typically in the size of pollen and thus undetectable using a stereomicroscope. Since this is the primary tool for conducting MLAS 2, I was not able to determine the presence of this type of fossil inclusions. None of the detected fossils contributed to an assignment of the material to a specific chronological sequence or depositional depth.
White coloured, irregularly shaped intraclasts are characteristic features in Meusnes flint (**Fig. 5.3.16. b)**.

Typical inclusions detected in Kraków "flint" are sponge remains highly varying in quantity, in some cases making up the entire matrix of the rock. They represent a sponge dominated Upper Jurassic fauna community **(Fig. 5.3.16. h, i, k, l).** Additionally, echinoderm remains (e.g., sea urchin spines; **Fig. 5.3.16. j**) and macrofauna inclusions (e.g., gastropods and shells) occur **(see Fig. 5.3.16. m)**. Geodes, mainly filling hollow spaces from dissolved fossil inclusions, are common features in Kraków raw material **(Fig. 5.3.16. n)**.

Lessini material (Biancone flint) is characterized by the presence of radiolarians (mainly preserved as "phantoms" and often compressed in the course of diagenesis **(Fig. 5.3.16. p, q, r, t,** with few exceptions, e.g., **Fig. 5.3.16. u)**, sponge remains (predominatly spicula; **Fig. 5.3.16. p, q**) and marine detritus. According to Binsteiner (1994, 260), flint from the Ceredo source can be best identified by the presence of tetractine spicula as the determining element **(Fig. 5.3.16. t)**. The majority however consists of monaxon spicula in partly large quantities. Large, mainly white coloured, irregularly shaped intraclasts are another typical feature of Biancone flint **(Fig. 5.3.16. r)**.

Meusnes flint	Kraków "flint"	Lessini flint
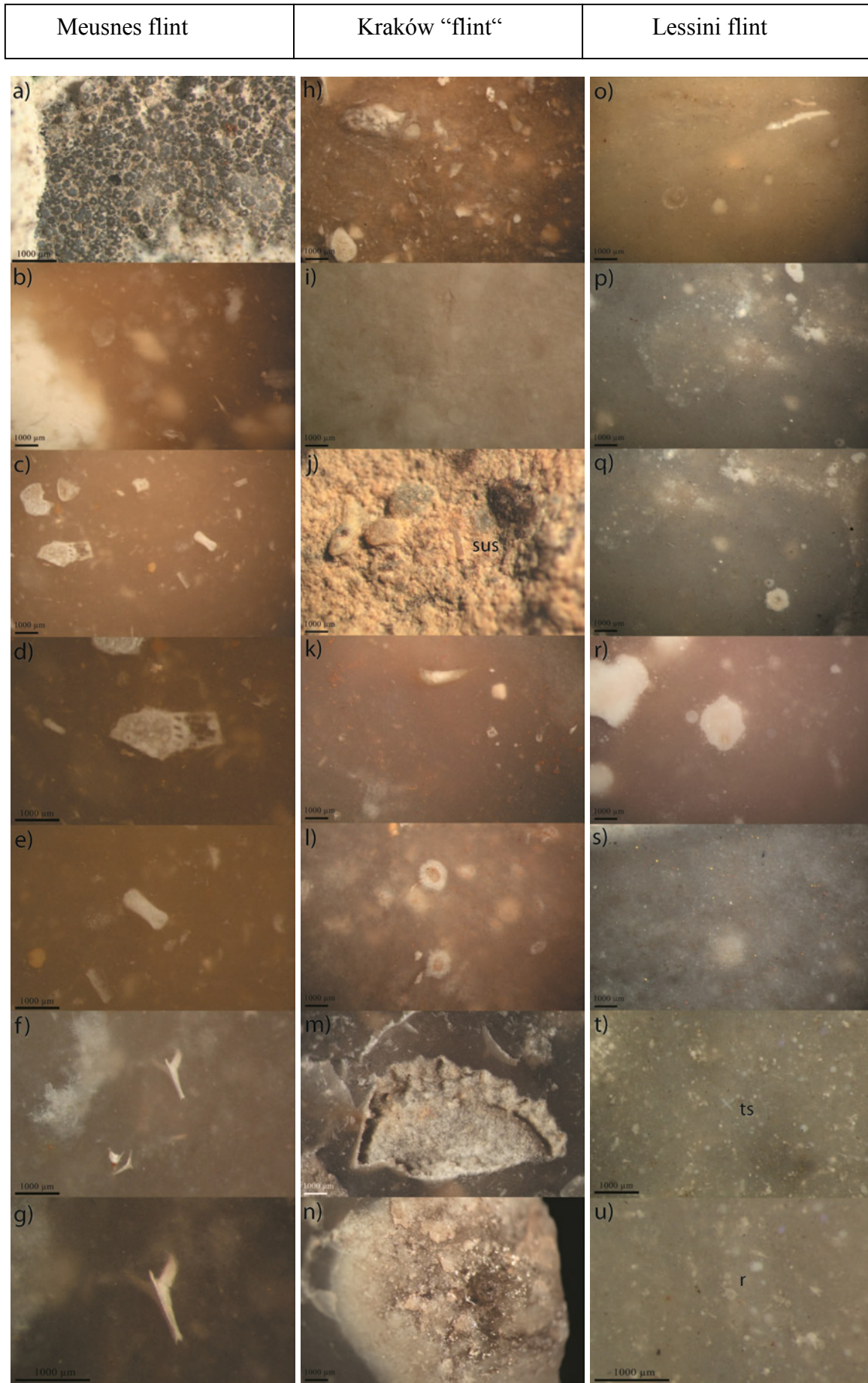
Fig. 5.3.16.: Micropictures of the comparative samples
Photos: M. Brandl.

Provenance of the samples in Fig. 5.3.16.:

a-g: Meusnes-Le-Quartier
h-j: Bębło; k, l, n: Mników; m: Czajowice
o-q: Ceredo; r : Monte Baldo; s-u: Sant'Anna d'Alfaedo

Key:
sus: sea urchin spine
ts: tetractine spicula
r: radiolarian

source		short code	fossil inclusions	inclusion sizes		texture
				max μm	**min μm**	
Meusnes		MEU	radiolarians (-95% content; dissolved in the course of diagenesis in the rock matrix, only visible at the transition zone cortex–rock matrix), echinoderm remains (skeletal remains and spines), sponge remains (spicula, parts of spongin skeletons, up to entirely preserved sponges), marine detritus and unidentifyable fossil remains	1000	50	crypto-crystalline
Kraków	Bębło	BEB	sponge remains (spicula–entire sponges, up to 99% of the rock constituents), echinoderm remains (mainly spines), macrofauna (gastropods, shells), marine detritus; geodes filling hollow spaces of dissolved fossil inclusions	3000	50	micro-/crypto-crystalline
	Mników	MNI		2200	50	
	Czajowice	CZA		2000	50	
	Sąspów	SAS		2500	50	
Lessinia	Ceredo grey	CER	radiolarians (-50% content, often less; mainly preserved as phantoms and diagenetically compressed), spicula (monaxon–multiaxial; tetractin spicula are considered typical for Ceredo grey flint), marine detritus	1100	50	crypto-crystalline
	Ceredo yellow	CER		1000	50	
	St. Anna D'Alfaedo	STA		400	50	

Table 5.3.5.: Microscopical properties of the comparative samples

Graph: M. Brandl.

5.3.5.1.3. Petrographical analysis

XRD and SEM analysis were conducted for the Rein – Baiersdorf and Radiolarite case studies, however for the present work it was neglected due to constraints bound to the detection limits of the relevant trace elements, as encountered in the course of the previous undertakings (see in Chapter *6. General discussion*).

5.3.5.1.4. Geochemical analysis

As demonstrated above, the Lessinian raw materials can be identified by means of MLAS 1 and, with much higher accuracy, applying MLAS 2. However, Lessini samples are included into the geochemical analysis in order to achieve a characterisation of distinct geochemical parameters for all source regions involved in the present case study.

Processes responsible for the presence of trace elements in chert and flint are discussed in detail in Chapter 4. Abbreviations used in the geochemical plots are linked to the sampled sites in **Table 5.3.5.** (microscopical description of the samples).

5.3.5.1.4.1. Distinction of the source regions

As demonstrated in the previous case studies, colouring cations are in most cases unsuitable for any source distinction. Fe, Mn, Ni and similar elements are enriched in intensely coloured areas and less concentrated in lighter rock parts, independent of the origin of the chert and flint samples **(Fig. 5.3.17.).**
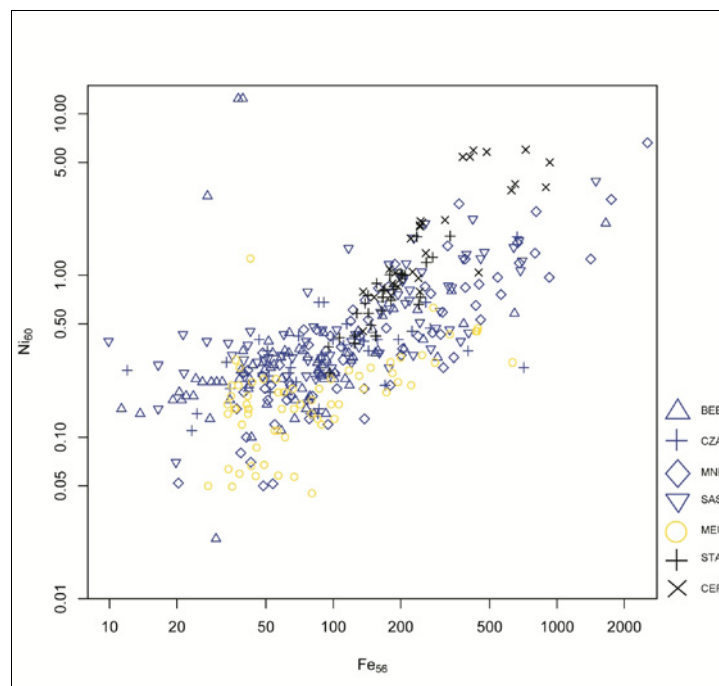
Fig. 5.3.17.: Iron versus nickel concentration plot
of all geological samples

Elements Li and B, best suitable for the distinction between lacustrine and marine silicites (e.g., Rein and Baiersdorf), are not usable for materials from purely marine depositional environments **(Fig.5.3.18.).**
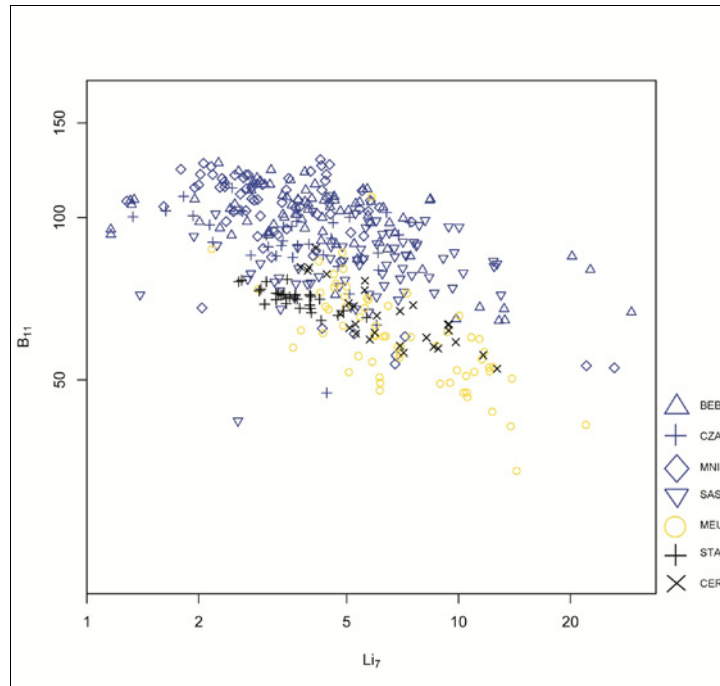
**Fig. 5.3.18.: Lithium versus boron concentration plot
of all geological samples**

High field strength elements (HFSE) such as Al, Ti and Ge are usually immobile and able to replace Si cations in chert and flint (e.g., Konhauser et al. 2003, 35). Since the investigated chert/flint raw materials were formed 1) under distinct depositional conditions, i.e. spatially divided, individualized marine basin environments and 2) during different geological periods, such elements are suitable for a distinction between the source regions.
Best possibilities for a characterisation are provided by the trace elements Ge in combination with Al, Mg, Ti, Cr and Ba **(Fig. 5.3.19.)**.
The same pertains to Zn combined with the aforementioned elements (e.g., Zn-Al, Zn-Mg; **Fig. 5.3.20.**). However, Zn inherits analytical problems and will therefore not be used to the same extend as Ge (*see discussion*).
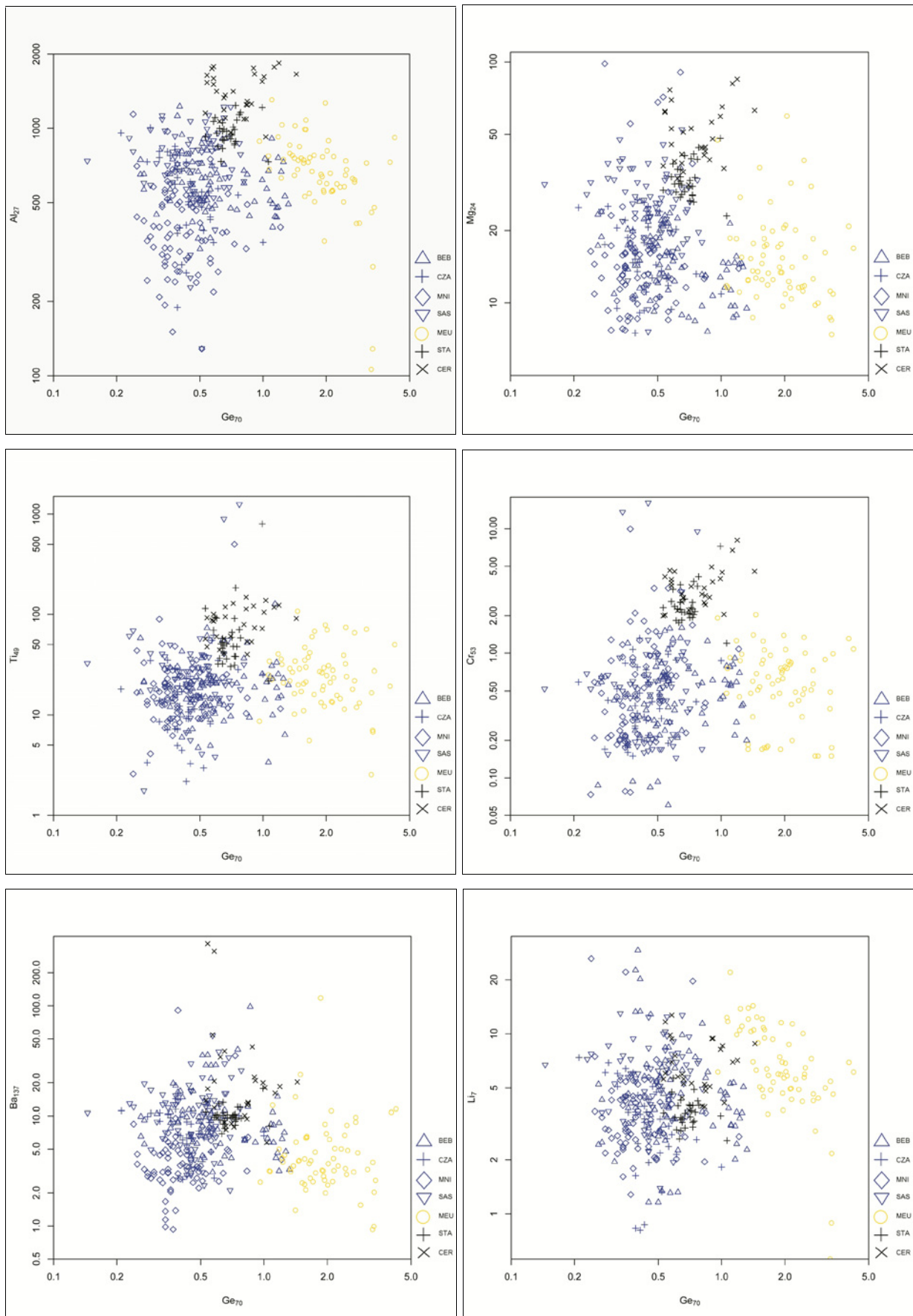
Fig. 5.3.19.: Germanium versus aluminium, magnesium, titanium, chromium, barium and lithium concentration plots of all geological samples

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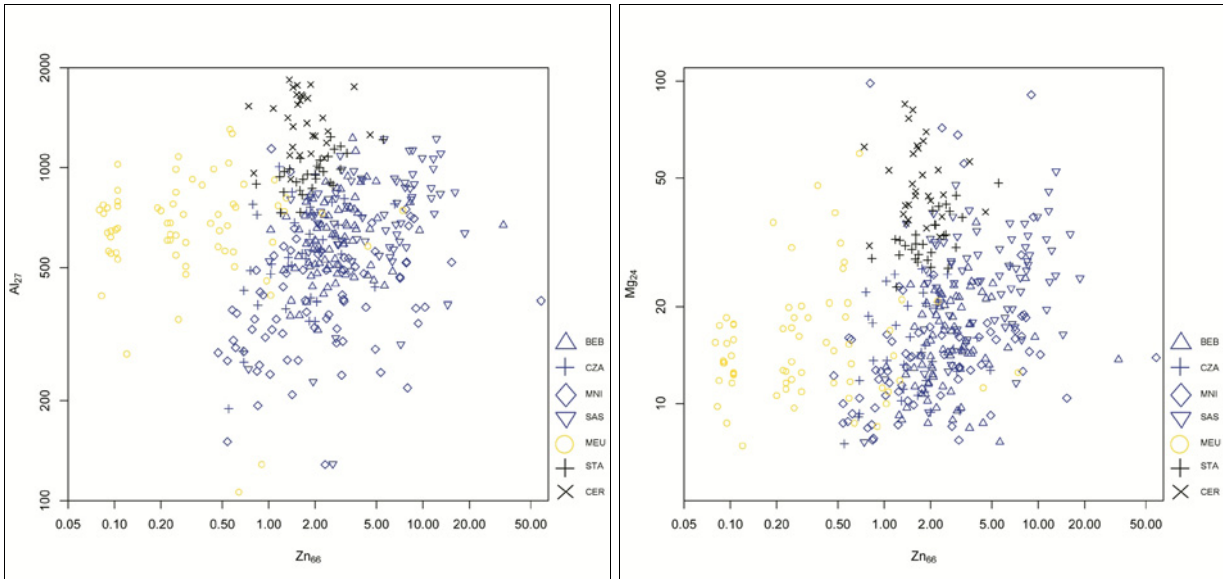
**Fig. 5.3.20.: Zinc versus aluminium and magnesium concentration plots
of all geological samples**

Trace elements Ba, Mg, Sr, V and Rb, inherently enriched in inclusion minerals such as
feldspars and carbonates, can additionally be deposited in pore spaces. Characteristic for
depositional environments of radiolarites in the Northern Calcareous Alps and the
Carpathians, they only provide limited possibilities for source distinction at the present
research question, as demonstrated in the Mg–Ba concentration plot **(Fig. 5.3.21.)**.
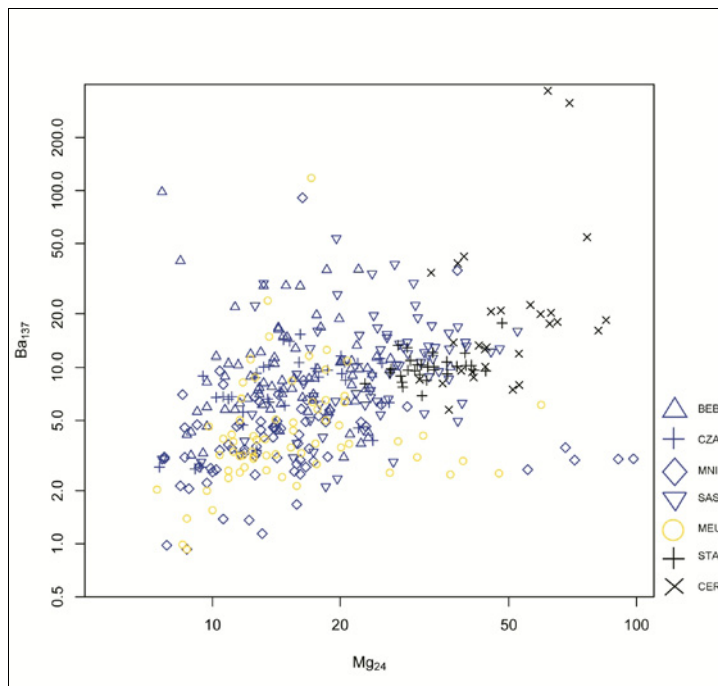
**Fig. 5.3.21.: Magnesium versus barium concentration plot
of all geological samples**

5.3.5.1.4.2. Lessini vs. Kraków & Meusnes

In most cases, the Lessini data cluster overlaps with data points from the Kraków sources. This is especially visible in the Al–Ge, Mg–Ge, Ti–Ge and Ge–Ba concentration plots **(Fig. 5.3.19.)**.

All samples from the Lessini Mountains show elevated chromium values and constitute a clearly defined source cluster using that trace element for a distinction. This is best seen in the Cr versus Al, Mg, Ti and Ge concentration plots **(Fig. 5.3.22.)**.
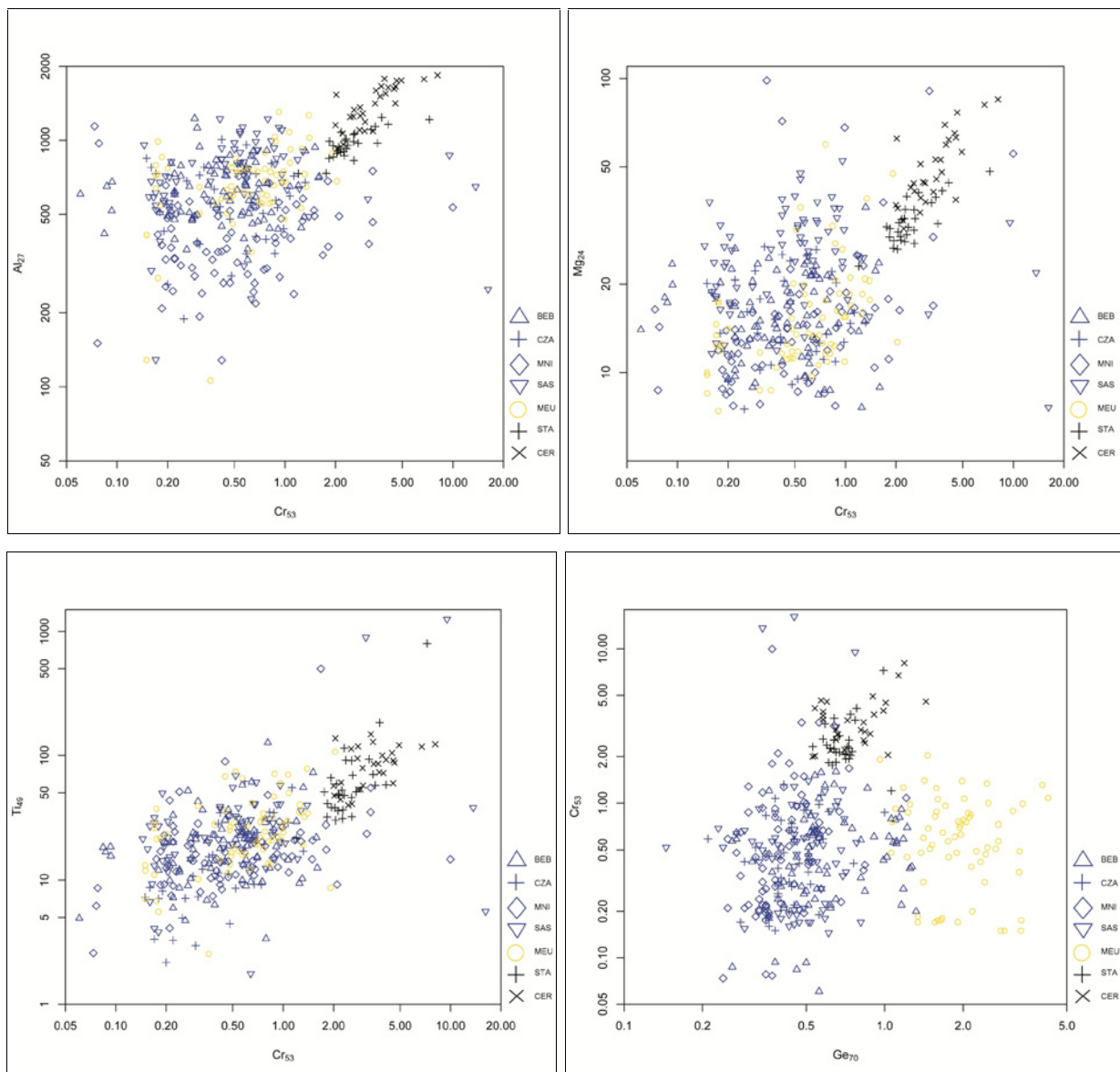
Fig. 5.3.22.: Chromium versus aluminium, magnesium, titanium and germanium concentration plots of all geological samples

However, some data points from the Kraków source region also overlap at the Cr–Ti, Cr–Mg and Cr–Ge plots, proving best applicability of the Cr–Al proportions for a characterisation of Lessini flint in comparison with Kraków and Meusnes material.

To a limited extent, a source distinction can also be achieved using the race elements Al and Ti **(Fig. 5.3.23.)**.
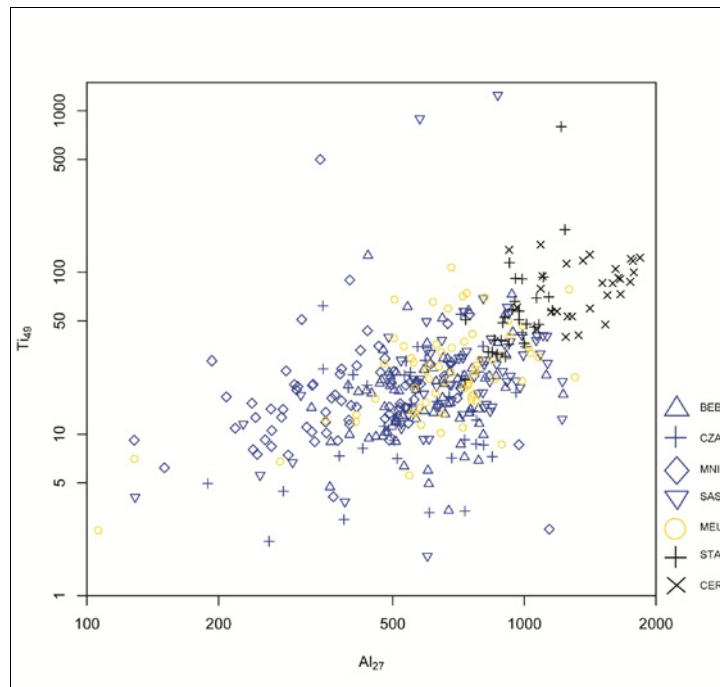
Fig. 5.3.23.: Aluminium versus titanium concentration plot
of all geological samples

5.3.5.1.4.3. Kraków vs. Meusnes

As demonstrated above, Ge in combination with Al, Mg, Ba and Li shows best results for a source distinction between the Kraków samples and the Meusnes data cluster **(Fig. 5.3.24.)**. The same is true for Zn, however the values exhibit low concentrations and are situated at the detection limit. Analytically, the correlation between Ge and Ti provides more reliable results, although minimal overlapping does occur **(Fig. 5.3.25.)**.
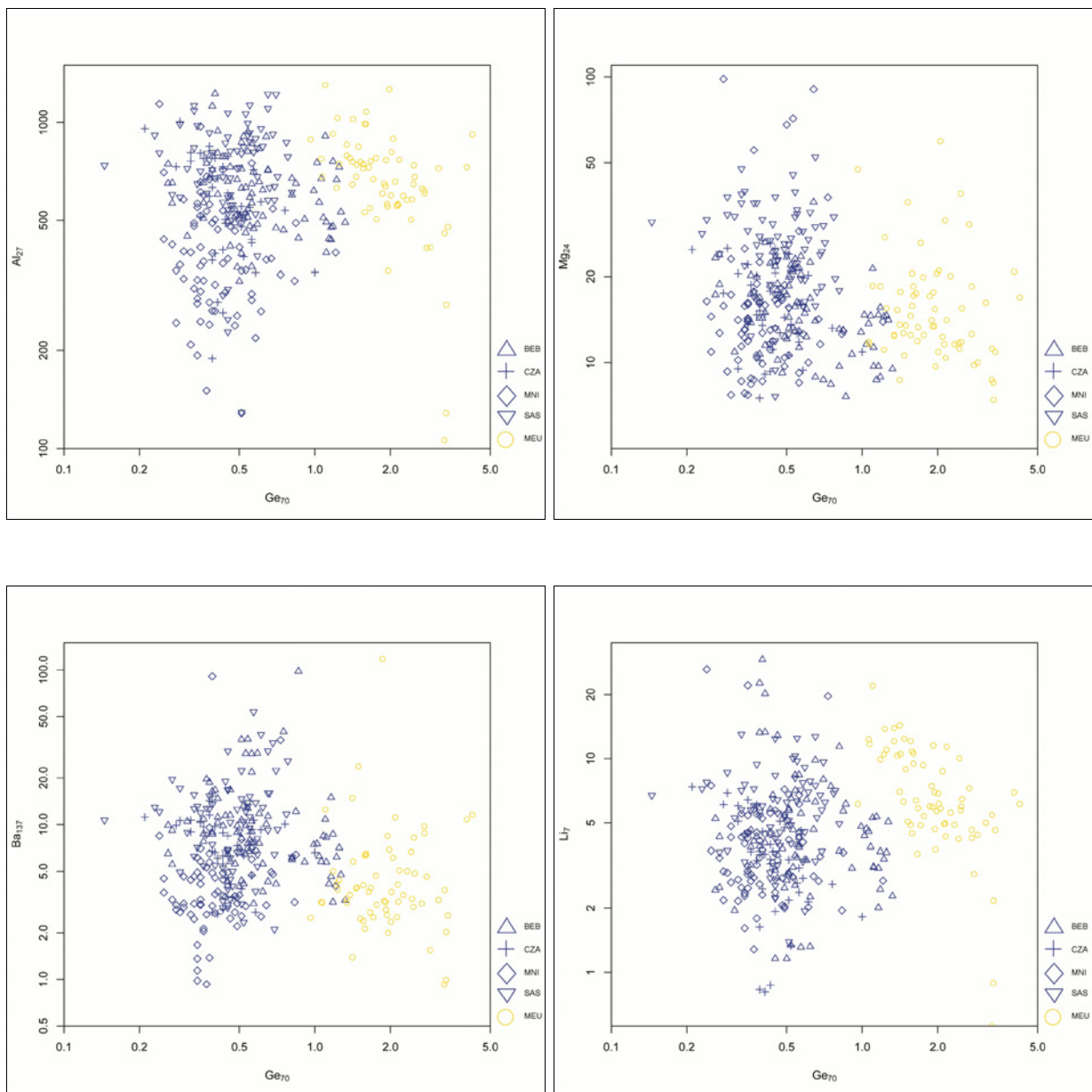
Fig. 5.3.24.: Germanium versus aluminium, magnesium, barium and lithium concentration plots of the Kraków and Meusnes samples
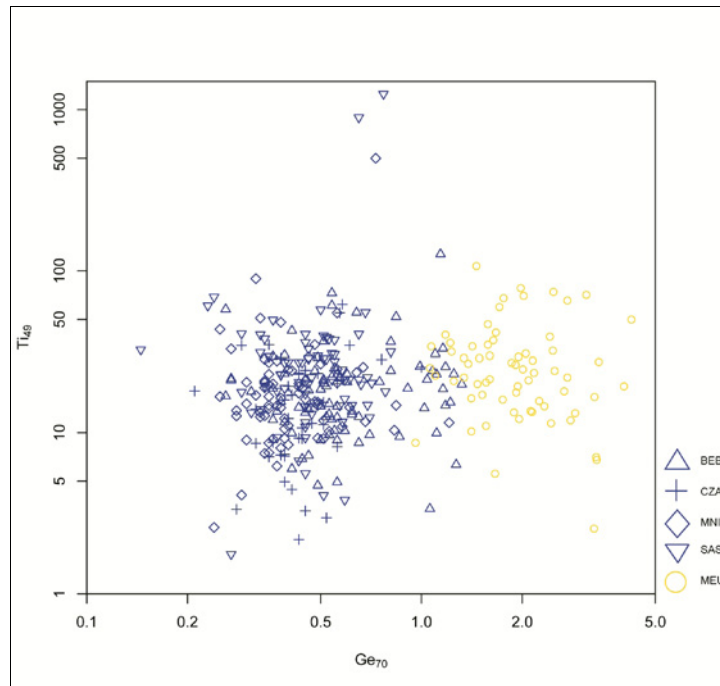
**Fig. 5.3.25.: Germanium versus titanium concentration plot
of the Kraków and Meusnes samples**

5.3.5.1.4.4. Kraków sources: Intrasource distinction

Only in the case of the Kraków source region multiple chert outcrops/mining sites were sampled. In the Lessini Mountains, Ceredo and St. Anna d'Alfaedo are situated in close vicinity and only reflect different geological source conditions (primary vs. residual) of the same geological setting. At Meusnes, only one outcrop relevant for gunflint production was sampled.

Therefore, only the Kraków source cluster allows for an intrasource-differentiation between Bębło (BEB), Czajowice (CZA), Mników (MNI) and Sąspów (SAS). Given the spatial proximity and the similar genesis conditions of the sources on the Kraków Upland, such a distinction can be only expected to a limited degree.

However, Sr in combination with V, Rb and Mn provides possibilities for a certain differentiation **(Fig. 5.3.26.)**. The Sr–V concentration plot allows for a vague distinction, predominantly between the MNI and BEB sources. A better separation is achieved by using Sr versus Rb, again mainly between MNI and BEB, and to a certain degree also involving the

SAS source; especially data points from CZA are insignificantly interspersed into the other data clusters.

Strontium versus manganese allows for a division between BEB, MNI and SAS **(Fig. 5.3.26.)**. Minor overlapping occurs at the SAS source, however data derived from the CZA source shows insignificant values. Vanadium and rubidium values are situated at the dectection limit, the Sr-Mn plots displays most relevant results for an intrasource distinction.
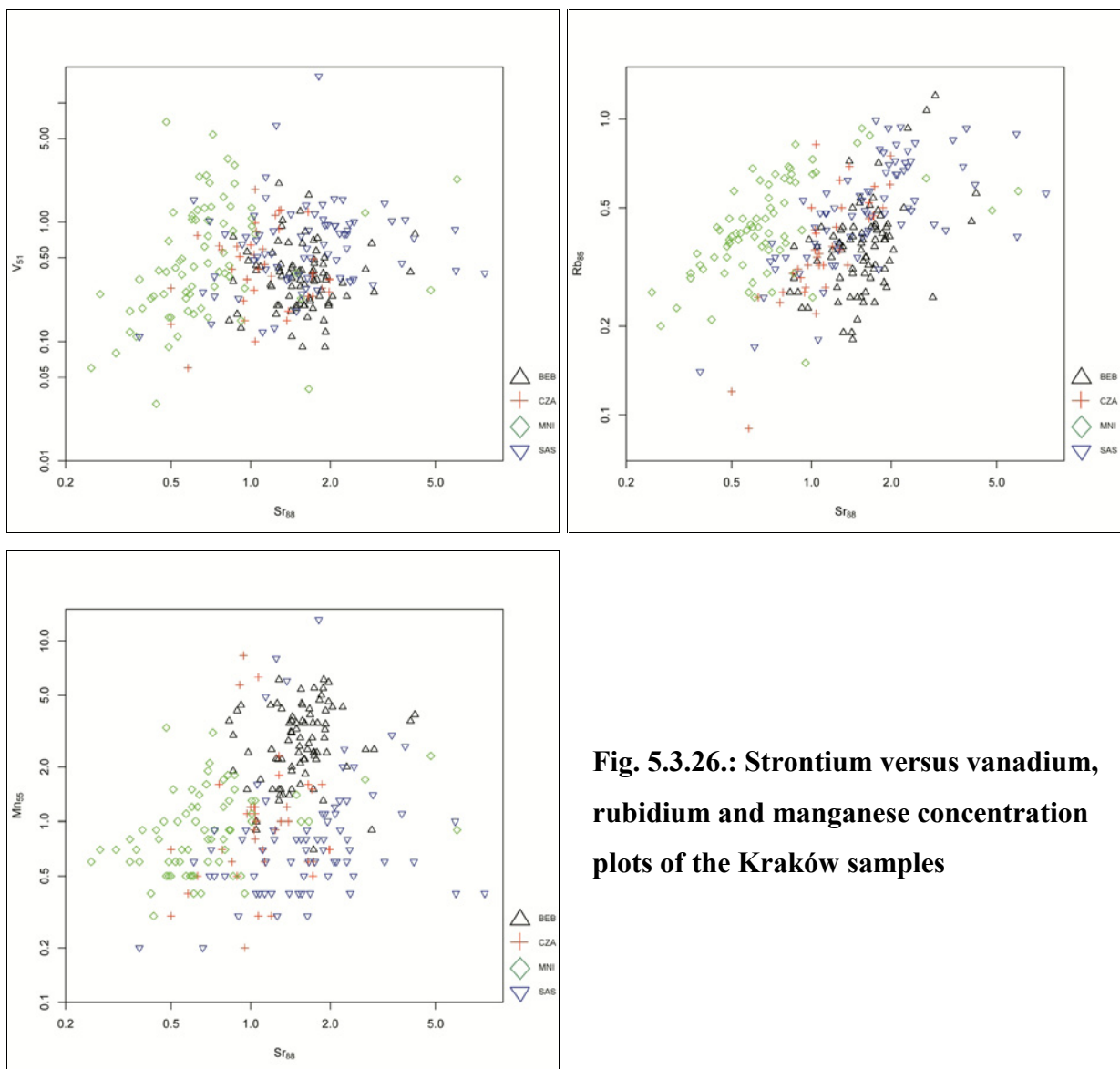
Fig. 5.3.26.: Strontium versus vanadium, rubidium and manganese concentration plots of the Kraków samples

5.3.5.1.4.5. Correlations with Ca

All analysed samples show relatively low Ca values, except for rare outliers containing carbonates. Such anomalies can be explained by inclusions in the chert and flint matrix. Additionally, the majority of the samples from all three source regions exhibit medium-high Al values, indicating clay minerals and/or plagioclase ($CaAl_2Si_2O_8$) with low Ca content (Ca:Al in a 1:2 ratio; **Fig. 5.3.27.**).

The MNI source generally shows low values in both, Ca and Al content, as well as the highest inclusion-related outliers. The CER source contains significantly higher Al values than the rest of the samples, which can be considered characteristic and useful for a distinction (see **Fig. 5.3.22.** Cr-Al).
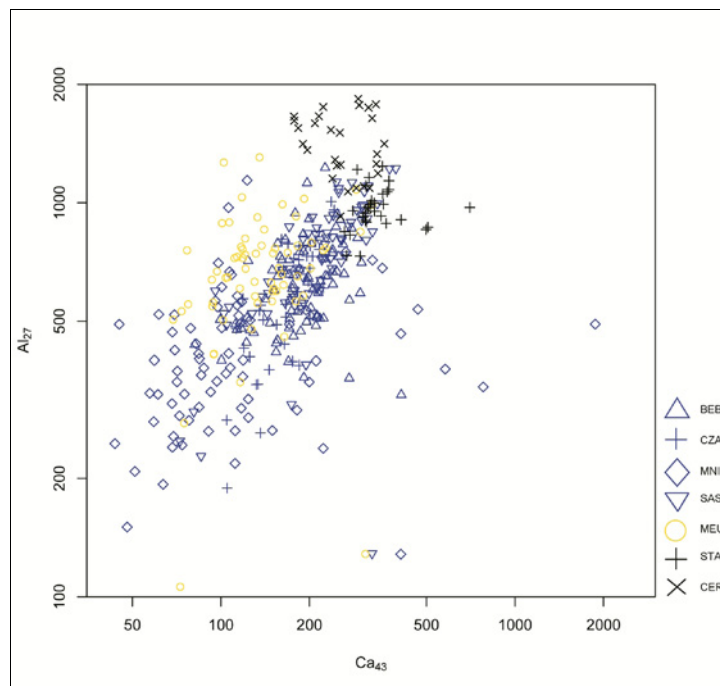
**Fig. 5.3.27.: Calcium versus aluminium concentration plot
of all geological samples**

The same trends are visible in the Ca-Mg correlation plot **(Fig. 5.3.28.)**; generally, the detected Mg values are low at all analysed samples except for the CER source, which correlates with the examinations of the Ca–Al concentrations.

200
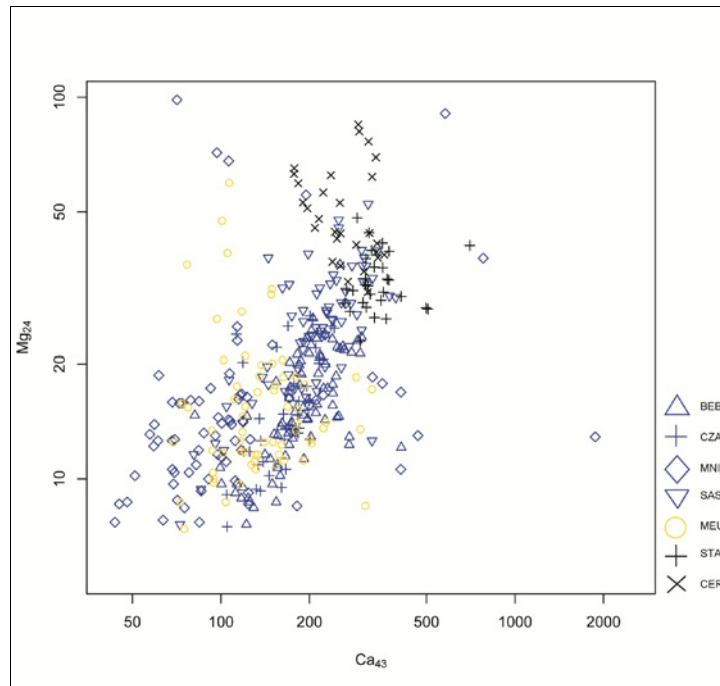
**Fig. 5.3.28.: Calcium versus magnesium concentration plot
of all geological samples**

Additionally, a correlation between Ca and Sr, which behaves geochemically similar to Ca, is present for the majority of the Kraków Upland and the Lessini samples **(Fig. 5.3.29.)**. The samples from Meusnes scatter insignificantly.
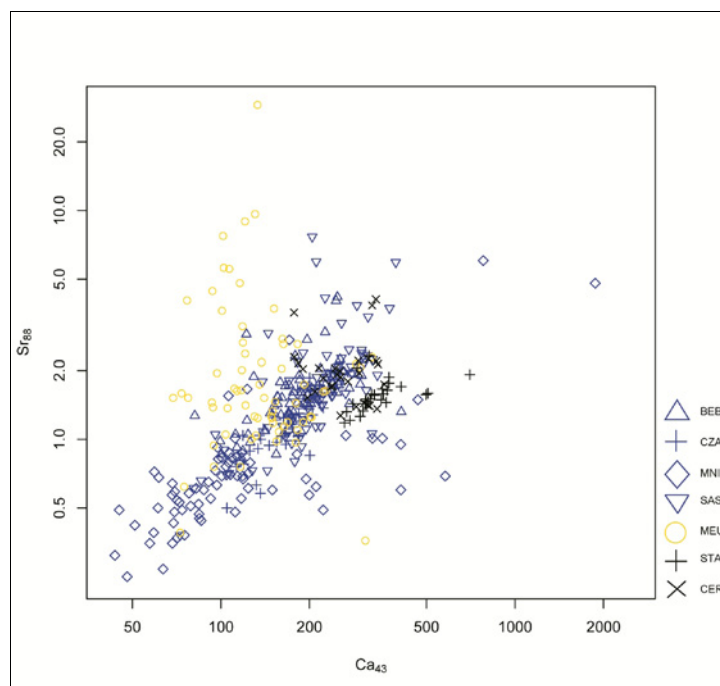
**Fig. 5.3.29.: Calcium versus strontium concentration plot
of all geological samples**

The Al, Mg and Sr versus Ca concentration plots demonstrate that some samples do not follow the trends discussed above due to the disparate element concentrations.

Due to the very low concentrations of mineral inclusions in all investigated samples, XRD analysis did not seem to be useful, as demonstrated at the radiolarite case study.

5.3.5.2. Application to the Schloss Neugebäude gunflints

5.3.5.2.1. Macroscopical, microscopical and geochemical results

Visually, Lessini flint is in most cases clearly distinguishable from the French and Polish materials and further analysis would not be required **(Fig. 5.3.30.)**; however, Woodall & Chelidonio (2006, 225) discuss difficulties in differentiating due to the high similarity between silex blond from Meusnes and the yellowish variety of Lessini flint. Therefore, additional microscopic investigations are necessary for a conclusive assignment.

In most cases, raw material from Meusnes, Kraków and the Lessinian Mountains is microscopically distinguishable. However, if an artifact does not contain characteristic fossil inclusions, an assignment is barely possible. Taking into consideration that raw material specifically used for gunflint production had to be as inclusion-free as possible, this constitutes a major problem due to the visual similarity of the raw material varieties **(Fig. 5.3.31.** and **Table 5.3.6.)**.

As demonstrated in previous studies, MLAS 3 provides most promising parameters for creating a "fingerprint" of raw material sources. For that reason, LA-ICP-MS was applied in order to obtain additional data for a clear assignment of the Schloss Neugebäude gunflints.

| Suggested origin: Lessini | Suggested origin: Meusnes | Suggested origin: Kraków |

Fig. 5.3.30.: Gunflints analysed for the study

Photo: M. Brandl.

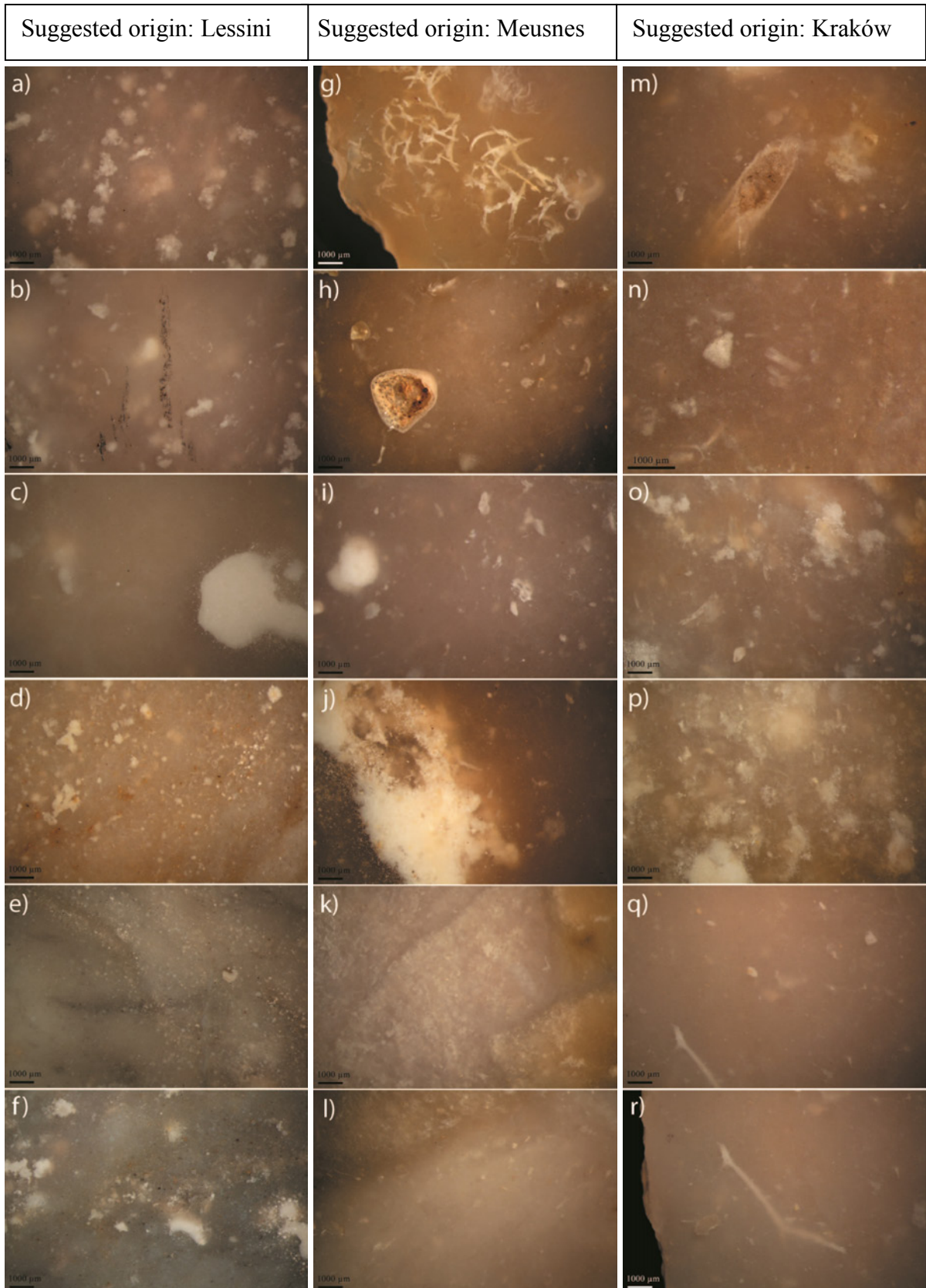| Suggested origin: Lessini	Suggested origin: Meusnes	Suggested origin: Kraków

Fig. 5.3.31.: Micropictures of the Schloss Neugebäude gunflints

Photos: M. Brandl.

suggested origin	micropictue	sample No	description
Lessini	a	239	SiO2-precipitations
	b	239	metal traces on gunflint surface
	c	240	intraclast
	d	241	spicula and dissolved radiolaria (phantom)
	e	242	spicula and radiolarians
	f	243	radiolarians, intraclasts and SiO2-precipitations
Meusnes	g	234	polygonal articulated sponge skeleton
	h	234	geode inclusion
	i	235	echinoderm remains
	j	236	sponge remains and SiO2-precipitations
	k	237	SiO2-precipitations
	l	238	spicula and marine detritus
Kraków region	m	244	echinoderm spine
	n	245	echinoderm spine fragment and marine detritus
	o	246	spicula and echinoderm spine fragment
	p	247	spicula and marine detritus
	q	248	echinoderm remains and detritus
	r	248	sponge skeleton remain

Table 5.3.6.: Microscopical description

of the sampled gunflints from Schloss Neugebäude

Graph: M. Brandl.

Geochemistry

As demonstrated in Section 5.3.5.1.4., Ge in combination with Al, Mg, Ti, Cr, Ba and Li provides best possibilities for a differentiation between the sources under discussion. However, when applied to the archaeological finds, certain trends do occur and need to be addressed.

The Al–Ge, Ge–Ti, Ge–Cr, Ge–Ba and Ge–Li concentration plots **(Fig. 5.3.32.)** display various possibilities for a distinction between the raw material sources and allow for an assignment of the majority of the sampled gunflints to distinct source regions.
As seen in the Al–Ge and the Ge–Ti correlation plots, some of the archaeological samples are not clearly related and need additional revision using Ge–Cr, Ge–Ba and Ge–Li. The above mentioned overlapping of Kraków and Lessini data points is obvious at the Ge–Ti, Ge–Ba and the Ge–Li concentration plots, however this does not constitute a major problem due to the fact that Lessini flint is characteristic in many regards; a clear geochemical distinction is seen at the Ge–Cr as well as the Al–Ge concentration plot.

Mg ratios detected at the geological comparison material from Kraków and Meusnes show significantly different values than the archaeological samples. However, this is no contradiction to our findings, most likely the elevated Mg values in the gunflints can be explained by depositional conditions (see "Surface alterations").
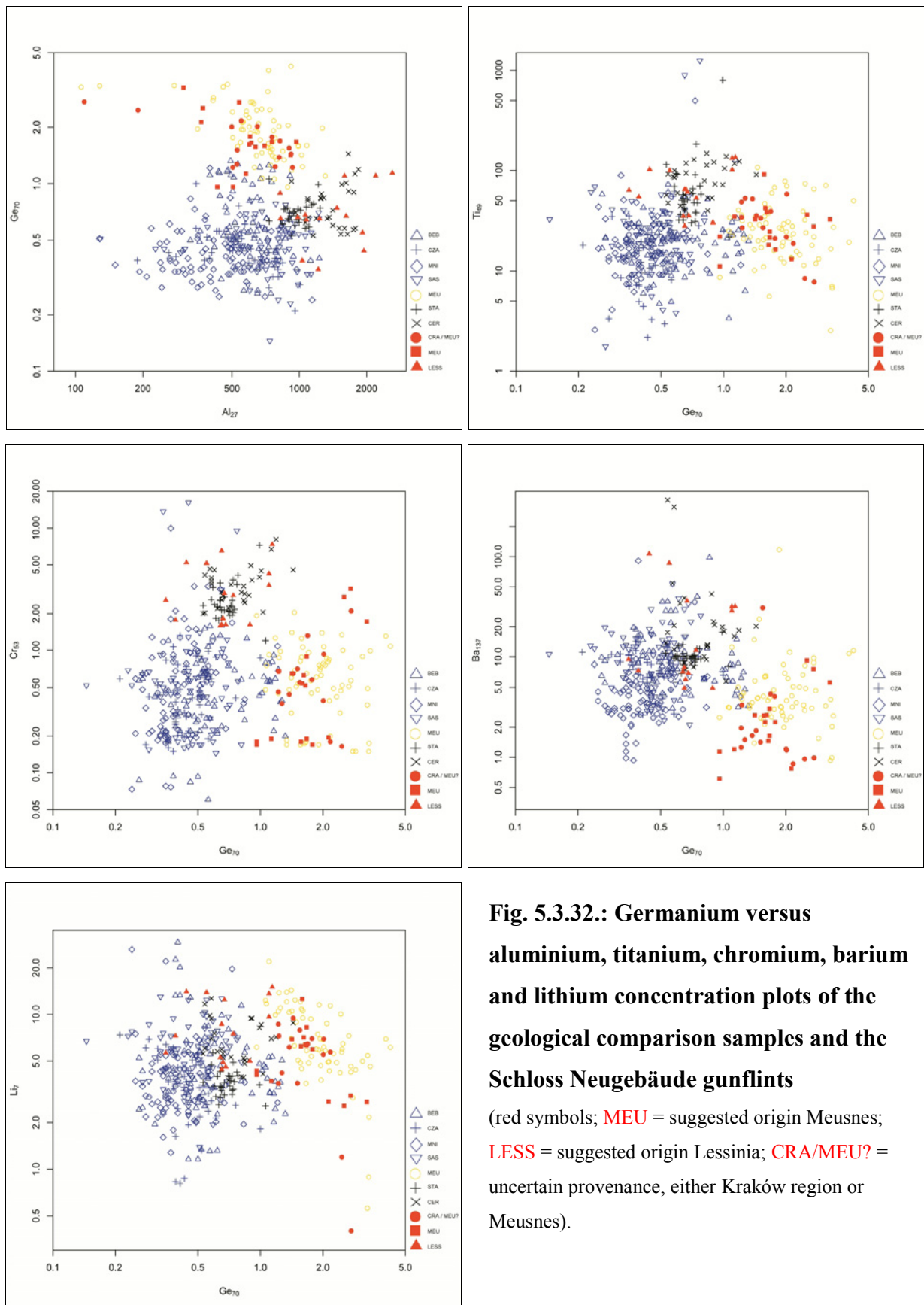
Fig. 5.3.32.: Germanium versus aluminium, titanium, chromium, barium and lithium concentration plots of the geological comparison samples and the Schloss Neugebäude gunflints

(red symbols; MEU = suggested origin Meusnes; LESS = suggested origin Lessinia; CRA/MEU? = uncertain provenance, either Kraków region or Meusnes).

Since Lessini flint and the related archaeological finds can in most cases be easily identified applying MLAS 1–3, the main research question focuses on the assignment of gunflints questionable to originate from Kraków or from Meusnes. A clear differentiation can be achieved using Ge–Ba **(Fig. 5.3.33.)** and Al–Ge **(Fig. 5.3.34.)**, placing all gunflints of uncertain provenance in the Meusnes data field.
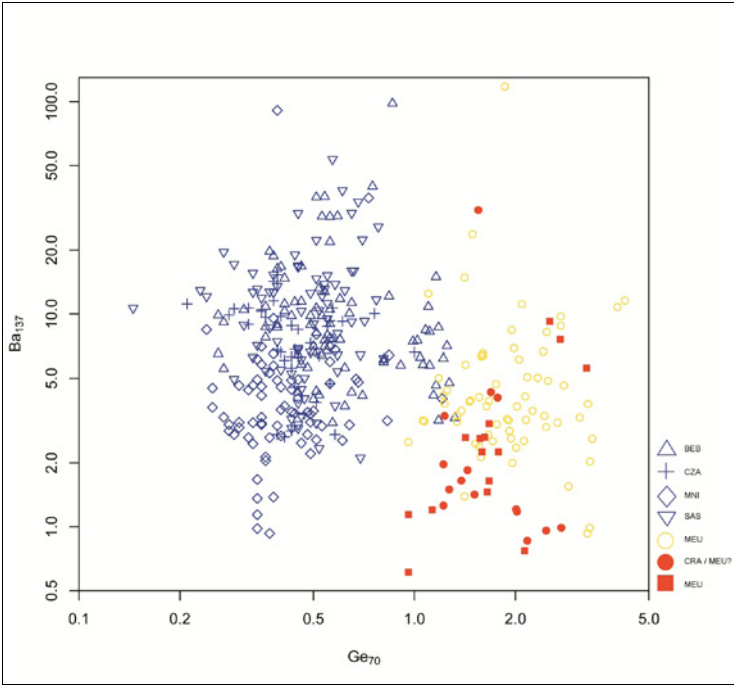
Fig. 5.3.33.: Germanium verus barium concentration plot of the geological samples from Kraków and Meusnes and the Schloss Neugebäude gunflints
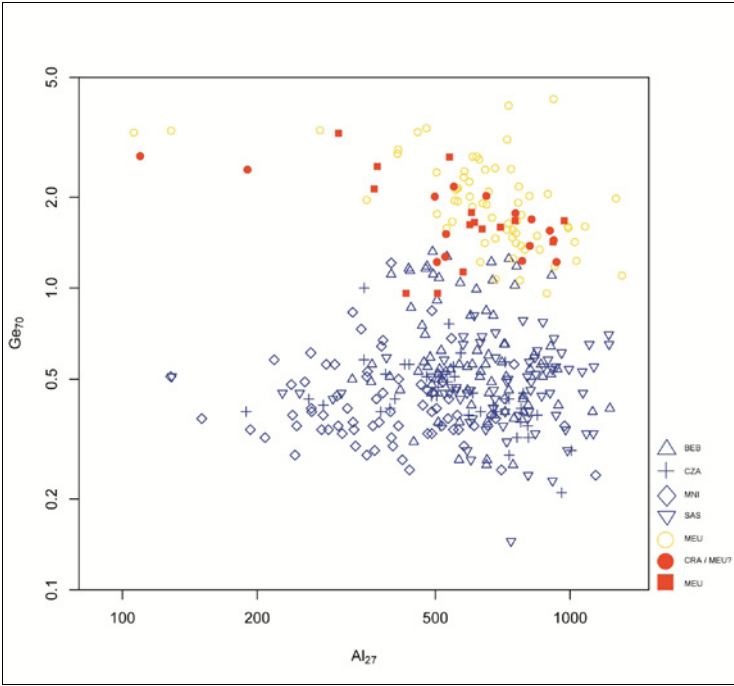
Fig. 5.3.34.: Aluminium versus germanium concentration plot of the geological samples from Kraków and Meusnes and the Schloss Neugebäude gunflints

5.3.6. Discussion

5.3.6.1. Chrono-technological assessments

The standardized format of the gunflints allows a chrono-technological assignment to the time period between the late 18th and the first half of the 19th century. Irregularly shaped and spontaneously knapped pieces are only characteristic for the early period of flintlock rifle technology in the 17th and the early 18th century and remain common exclusively for civilian use throughout the history of gunflint utilization (Penz & Trnka 2004, 240).

The specific horseshoe-shaped gunflint type present at the Schloss Neugebäude cache is characteristic for the French military standard, whereas square specimens with two parallel ignition edges where only intended for civilian use in France. In England, Holland and Spain, square gunflints were commonly used for both military and civilian purposes (Skertchly 1879, 36, 46-64; Weiner 2012, 965-970). Rarer examples were cut and polished, but never gained great importance for standard equipment (Skertchly 1879, 63; Slotta 1980, 354).

The sizes of the gunflints from Schloss Neugebäude on the other hand are highly variable, indicating intermixture of different contingents. Typically, gunflints were packaged according to their size, i.e. their assignment to types of firearms requiring different formats of flintstones (Seel 1981, 1456). The presence of various raw material types is an additional evidence for widespread procurement regions for the stock (Penz & Trnka 2004, 242-243).

As demonstrated above, there were only two sources of historical importance in the Austrian Monarchy concerning the production of gunflints, the Upper Italian Lessini Mountains, temporarily restricted due to political events, and the former Polish possessions of the Empire. The presence of Lessini material in the Neugebäude assemblage was already established by Trnka & Penz (2004) and Affolter (2004).

Lessinian gunflints from Schloss Neugebäude

According to the available references, it seems likely, that horseshoe shaped gunflints (French style) do not occur before 1797 in Lessinia (due to French influence since Napoleons "Italian

Campaign" 1796/97 and occupation from 1806-1815). After 1806, it is very plausible that the French interdicted gunflint production in the area in order to block the Austrian army from this branch of gunflint supply; Lessinian gunflints could then only be obtained via smuggling. Referring to the information, that the entrepreneur Boldrini exported "100 barrels" of Lessinian gunflints to Austria during the Napoleonic Wars (Solinas 1953, 111), I conclude that this happened between 1797 and 1806 (taking the aforesaid into account). From 1806 until 1815, the amounts of Lessini gunflints supplying the Austrians can not have been very substantial. After 1815, we see a drastic decrease in the demand for Lessini gunflints, indicated by the letter Gaetano Boldrini submitted in 1817 (Andreis & Chelidonio 2008, 160, 163 footnote 1).

As a consequence, it is very likely, that the gunflints from Lessinian material in the Schlosss Neugebäude cache (several hundred kilograms!) were produced between 1797 and 1806.

Kraków chert or Meusnes flint?

The determination of the "last holders" of the Neugebäude gunflints was dependent on the provenance of the major contingent of the assemblage, the "silex blond"-type variety. Since Polish material is expected in Austrian army supplies during the discussed timeframe, raw material investigations mainly concentrated on identifying if Kraków "chert" is present in the gunflint cache, or if it is exclusively French material.

5.3.6.2. Raw material analysis

Macroscopical/microscopical investigations

Possibilities for source distinction applying macroscopic and microscopic analyses range from "clearly definable" to "non-determinable". These are dependent on characteristic visual appearance and microfossil inclusions of a specimen compared to "typical" material from a source and/or source region. For securing preliminary results obtained from MLAS 1 and 2, mineralogy/geochemistry (MLAS 3) is a compulsory analytical step.

Mineralogical investigations

Due to the experiences from the earlier case studies XRD and SEM analysis were not conducted for the present undertaking. In all examined samples, low element concentrations exceed the detection limits. Especially the low Ca contents detected at the gunflint samples rendered the determination of Si in the chert and flint samples redundant.

Geochemistry

The only previous case study dealing with the geochemical characterisation of gunflints applying LA-ICP-MS was conducted by Stevenson et al. (2007, 49-62). They investigated on gunspalls from Fort Christanna in Virgina, a frontier trading center of the early 18th century. Gunspalls from that Fort were considerd to originate from European sources and were therefore investigated for provenance studies. Their research concentrated on the differentiation between Britisch (Suffolk), French (Meusnes) and Danish (Stevns) flint. This was best achieved by projecting U (uranium) and Rb (rubidium) contents in the artifacts and raw material samples. The extension of the present gunflint study will provide possibilities to compare results and discriminant factors to those from Stevenson et al.

At this present case study, geochemical results indicate the potential for a differentiation between visually similar raw materials used for gunflint production, generally referred to as "*silex blond*" (given a certain range of coloration). This particularly involves Ge in combination with other trace elements, which in some cases show values situated within overlapping boundary zones.
Germanium is used for this study despite the fact that the contents are partly close to the detection limit.

Germanium (Ge) is considered an important biochemical index for ocean environments. In contemporary oceans, Ge occurs in the seawater in both, inorganic and organic form. Sources for inorganic Ge are predominantly hydrothermal activity and river influx. Important contributors to organic Ge are biogenic opals and Fe-rich clays with high Fe^{2+} availability (Kolodny & Halicz 1988, 2333-2336; Shen et al. 2011, 323). According to Shen et al. (2011, 324), "*certain organic molecules are known to have a high affinity for Ge due to their strong*

metal ion-chelating properties". Removal of Ge from seawater happens by accumulation in diatom frusteles (Si-skeletons). Due to that fact, Kolodny & Halicz (1988, 2335) consider diatoms to be controlling factors of the general Ge-content and seawater chemistry. According to Taylor & McLennon (1985, 15, Tab. 2.3), Ge is removed from sea water in a considerably short time span, with a mean ocean residence (MOR) time of ca. 2000 years.

Porewaters involved in chert precipitation can also be rich in Ge-dominated organic complexes (Shen et al. 2011, 323). Kolodny & Halicz (1988, 2333-2336) investigated chert samples derived from the DSDP and described a trend towards an increase of Ge in deep sea cherts with age rather than with depositional depth. The oldest samples (Late Juarssic) displayed an average Ge content of 0,9 ppm, the youngest (Late Eocene) 0,23 ppm. This trend is explained by the increasing abundance of diatoms in the seawater in younger sediments.

Ge values in the samples analysed for the present case study range between 0,2 and 4 ppm. The Meusnes flint samples show the highest Ge values with the majority ranging from 1 to 3 ppm. Kraków material is situated between 0,2 and 1 ppm Ge content, while Lessini flint ranges between 0,3 and 0,9 ppm.

These findings display an inverse trend when compared to the results presented by Kolodny & Halicz (1988, 2335). Their data indicates a correlation between elevated Ge values with an increase of the age of chert. Conversely, the samples from the present study show a decrease of Ge with the younger chert/flint exhibiting the highest Ge values and the oldest chert exhibiting the lowest values. However, Kolodny & Halicz (1988) only analysed samples from geological sequences at one locality, whereas the samples for the gunflint study derive from three spatially distant sources.

The most probable explanation for such a disparity are the individual geological settings of each source region investigated for the gunflint study: Meusnes flint was formed in Upper Creatceous, clay-rich limestone in shallow coastal water environments; Jurassic Kraków chert is bound to a microbial (sponges-)megafacies under shallow water conditions, and Lessini flint was formed in thick-layered micritic Biancone-limestone at a Cretaceous pelagic zone. Numerous factors involved in the chert/flint formation processes, most of them untraceable, had significant influence on the Ge content in material from the different sources. This is also the explanation for the insignificant Mg–Ba correlation of the gunflint samples.

In contrast to Germanium, Zinc (Zn) needs to be treated with higher precaution. The gunflint samples display very low Zn contents, especially at the Meusnes source. Furthermore, a trend is visible at 0,2 ppm, marking a detection limit as analytical artifact, which lowers the reliability of Zn for comparison studies. However, Zn values were only used for a differentiation between Kraków and Meusnes, and the data clusters are very distinct, compensating the analytical error in the lowermost ranges.
Source of Zn in marine sediments are predominantly planktonic remains (Piper 1994, 99).

Due to the fact that the Lessini samples could already be separated in earlier analytical phases (MLAS 1 and 2) and in the course of geochemical analysis (MLAS 3), the most crucial research question was concentrated on the differentiation between Kraków and Meusnes. Previous chemical analysis (Atomic Absorption Spectrometry, AAS) of Kraków chert samples conducted by Kaczanowska et al. (1979, 182-185) detected mostly elevated Fe values, however Fe is not applicable for source distinction. A clear differentiation was achieved in the course of the present study employing LA-ICP-MS, which confirmed the existence of purely French raw material and excluding the possibility of Kraków chert amongst the investigated gunflints.

5.3.6.3. Archaeological context of the gunflint cache

As demonstrated by the chrono-technological analyses, a time frame between ca. 1800 – 1840 can be taken as certain for the production of the Neugebäude gunflints, narrowed down by the Lessinian component of the assemblage most likely produced before 1806.

Unfortunately, only little is known about the incidences directly linked to Schloss Neugebäude between 1805 and 1848. In the course of the Napoleonic Wars (1800 – 1814/15), Austria was under attack twice, during the 3rd Coalition with Russia, England and Sweden in 1805 and again in 1809 in consequence of the Austrian rebellion against the French heteronomy (during the 5th Coalition, between Austria and England). At both occasions, Vienna was occupied, and Schloss Neugebäude served as a military camp for Napoleons troops. The invasion of 1805 passed off largely peaceful, however incidences following the siege and conquest of Vienna on May 11, 1809 escalated and resulted in significant

destruction of the surrounding areas. The crossing of the Danube by the French army prior to the battle of Aspern on May 21/22 required tremendous amounts of wood for the construction of temporary bridges. Parts of that wood were obtained by deconstructing the provisional roof of Schloss Neugebäude installed during the era of Maria Theresia. At first, the Austrian army succeeded over the French at Aspern, but was defeated at Wagram on July 5/6. Subsequently, Austria had to accept the conditions of the "Peace of Schönbrunn" on the 14th of October, and Napoleon left Vienna two days later. Altogether, he had resided for 158 days at Schloss Schönbrunn, his troops left Vienna on November 19 (Ackerl & Kleindel 1994, 286-292; Verein Schloss Neugebäude 2006).

The possibility, that the gunflint stock was part of the Austrian army equipment before the Napoleonic wars and remained at the Neugebäude deposit during all military activities nearly untouched is highly unlikely. A deposition by French forces in 1805 is also improbable[44] due to the fact that they returned in 1809, and the Austrians would certainly have removed these war-relevant products before the invasion.

The Austrian army started to modify their guns for percussion ignition around 1830 (Hirtenfeld 1852, 395), flintlock rifles completely lost their importance after 1840 (Weiner 2012, 961) and consequently Austrian arsenals kept only small stocks of gunflints after the transition to the percussion system after 1841 (Hirtenfeld 1852, 401). If the Austrian army was in the possession of the stock before it was deposited, this happened after 1840.

The reconstruction of storage spaces at Schloss Neugebäude after 1774 (the year of its assignment to military purposes) allows for the following statements:
The regular ammunition stores were located in the "Souterrain" under the main Palace building, the gunpowder was stored in the adapted towers of the embracing wall (Kefeder 39-40, 102 fig. 26). A print from 1818 from the Bezirksmuseum Simmering shows the production of artillery at the area of the palatial complex (Kefeder 2010, 103, fig. 28). At this time, flintlock rifles were still in use in the Austrian army. If a cache of military goods left behind by the French army would have been available, the Austrians would certainly have used it, especially since the Monarchy was bankrupt after 1809.

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[44] Although it is historically proven that Napoleon, in the course of the Peace of Preßburg on December 28, 1805, proclaimed to the people of Vienna: "Empfanget bey Meiner Abreise als ein Geschenk, das Euch Meine Achtung beweiset, unberührt Euer Arsenal zurück, das die Rechte des Krieges zu Meinem Eigentum gemacht haben..." (Brandstätter 1986, 197).

This leads to further conclusions:

1.) If Napoleon left the cache behind, it was not accessible to the Austrians.

2.) If the stock belonged to the Austrian army, it was dumped after the conversion to the more advanced percussion system for rifles around 1840.

One thing at least is obvious from the archaeological context: In the final state of deposition, the cache had been buried.

According to chrono-technological assessments, the time frame for the production of the Schloss Neugebäude gunflints can be narrowed down to the time period between the late 18th century (standardized format) and ca. 1806 (by the Lessinian component of the cache). If applicable, at least the Lessini gunflints would have belonged to the Austrian army, obtained during the short time span that Austria was in possession of the Lessini area during the Napoleonic wars. This assessment provides us with a terminus post quem regarding the deposition of the cache.

Napoleons conquest of Vienna dates exactly to the same time period, to 1805 and again 1809. The most important question concerning the "last holders" of the Neugebäude cache was determined by the raw materials contained in the assemblage. Since Galicia was the most important official gunflint supplier for the Austrian army with its peak between the turn and the first half of the 19th century, Polish material would certainly be present if the cache in its final composition was Austrian.

Taking all facts into account, the following scenario is most likely:

In the course of the war activities in 1809, and most likely after the defeat of the Austrians and the conquest of Vienna, stocks of the Austrian army entered into Napoleons possession. The Lessinian gunflints from Schloss Neugebäude were part of these supplies. After the plundering of the city Napoleons troops withdrew in November 1809, carrying away with them captured goods by the tons (compare e.g., Steinmann (2007, 393) reporting on art robbery in 1809, in the special case over 400 paintings from Schloss Belvedere). Brimming with valuables, it is comprehensible that the soldiers were unwilling to carry back tons of gunflints, especially since the French were in possession of the most important sources during this time, with the exception of Brandon.

In order to withhold the defeated Austrians from an easy access to important military supplies, it is more than probable that Napoleons troops chose the easiest solution and buried the gunflints, hidden in a secluded area of their camp, the Löwenhof of Schloss Neugebäude. When earthwork was eventually conducted in the second half of the 20th century, parts of the cache were unearthed and deposited in the initially mentioned arch alcove of the enclosure wall of the courtyard. Unauthorised collecting reduced the cache significantly until its archaeological recovery and securing in 2002.

6. General discussion

6.1. Analysis method

As demonstrated in the present case studies and previous undertakings, macroscopic and microscopic analyses are in most cases not sufficient to clearly assign archaeological artifacts to their source region.

Due to that reason, analytical techniques have been applied to archaeological research questions pertaining to the origin of lithic raw materials. Chert source provenance studies using trace element analysis techniques are an especially difficult undertaking due to the usually heterogenous nature of the samples and low element concentrations (Speakman et al. 2002).

As indicated in Section *1.3. Previous studies*, a range of natural scientific methods was applied in the past. However, only few chert sourcing approaches applying LA-ICP-MS have been conducted so far (Delage 1997; Roll et al. 2005; Morgenstein 2006; Evans et al. 2007; Speakman et al. 2007). These pilot studies – as is often the case – did not explore the entire range of possibilities a technique provides in order to maintain a narrow range of focus in order to determine the efficacy of a method (Tykot 2004, 64).

In most cases, only small amounts of samples were analyzed and definitive geochemical source specific patterns in terms of trace element compositions could not be established (Roll et al. 2005; Morgenstein 2006; Hughes 2010). Besides few clear-cut clusters, the microfacial heterogeneity of samples within the sources was detected in most cases (Evans et al. 2007). As a matter of fact, samples from different sources within a considerable catchment area showed higher coincidences that such from the one one single ourcrop. This is due to the throughout similar geological genesis of cherts compared in previous provenance studies.

As demonstrated by the previous studies applying LA-ICP-MS, the main problems occurred (1) due to the small amount of samples analyzed and (2) the throughout similar geological genesis of cherts compared in provenance studies. This is due to the marine origin of the majority of chert and flint (McBride 1979). Analysing only a small amount of samples additionally increases these problems due to the lack of relevant statistical evaluation. Method

inherent restrictions are the sometimes small sample sizes and spatially-resolved analysis (40-80 µm spots). Additionally, analysing heterogeneous spots on the specimen can distort the results (Speakman & Neff 2005, 9).

A considerable advantage of Laser ICP-MS is the possibility of a relatively non-destructive analysis, which meets the requirements for investigating archaeological material. Furthermore, LA-ICP-MS allows for the detection of main- (1-100%), side- (0.1-1%), trace- (1-1000 ppm) and ultra-trace elements (< 1 ppm) and the rapid analysis of many elements simultaneously (ca. 50 elements in our studies).

The present case studies

In order to create a geochemical fingerprint of chert raw material that is useful in sourcing archaeological artifacts, it must be generally implied that the analyzed material is not heavily altered by weathering effects (Tykot 2004; Hughes 2010).

For each presented case study, a relevant amount of comparative sources from areas suspected to be the origin of the analysed archaeological artifacts were sampled. If representative sample material was not available from geological outcrops, samples were preferably chosen from nearby archaeological sites. It is well known that adjacent source workshop material provides the best representative sample of mined outcrops. The chert sources chosen for the current undertaking are in most cases well known and subject to earlier investigations, but never have been analysed in a systematic manner. Until now, a methodological broad scale investigation of SiO_2-raw materials has not been carried out in European archaeology.

Many chert sources are comprised of sequences displaying several chronostratigraphic units. This is true for chert deposits in the vicinity of Kraków, where an outcrop can contain Triassic, Jurassic and cretaceous elements, as well as, the radiolarite source at Vienna Mauer with red Aptychen-layers and independent sequences bearing black radiolarites. Similar situations are found within the Lessini Mountains, the Allgäuer Alps, and even at the Rein Basin within a considerably small source area. Some approaches suggest the analysis of the complete geological profile at a source in order to gain most accurate results concerning the raw material actually used for prehistoric stone tool production. However, such undertakings

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get in most cases lost in the detail and miss the essential goal.

For the present case studies, a preselection was made based on the archaeological evidence. As mentioned above, close-to-source-workshop debris provides the best comparative material from sources that were prehistorically exploited. In many cases, the raw material preferred by the prehistoric people is not available any more. Only if it was assured that geological units are relevant for prehistoric raw material procurement they were sampled for comparison studies. If necessary, the investigated geological units at are distinguished as "RSS" (= relevant stratigraphic sequences).

In order to avoid distorted results deriving from small sample, spatially-resolved analysis and randomly analysed impurities (e.g., foreign mineral inclusions), the most representative rock parts were chosen for the investigations and the spots for analysis were selected with the highest possible caution.

As mentioned in Chapter *4. Analytical techniques*, naturally occurring inclusions in chert materials were monitored in every single case. In most cases they represented the natural range in the composition of the analysed chert raw materials, and anomalous peaks were only levelled when substantial distortion of the results was expected. Thus, the highest possible accuracy could be achieved for the geochemical results.

In the present case studies, raw material sources under discussion showed distinct geochemical parameters and were analyzed together with archaeological samples under the same measurement conditions. Our geochemical results indicate the potential for a differentiation between chert raw materials from distinct source regions through the investigation of trace element concentrations. In my opinion, this makes LA-ICP-MS as an integral component of the MLA one of the most promising analytical approaches for provenance studies on biogene SiO_2-varieties for the near future.

6.2. Theoretical implications

As indicated in Chapter 3, generalized models regarding inferences of human behaviour can be perilous for the assessment of raw material procurement strategies. Human behaviour never follows generalized laws. Archaeological data rarely allow for a clear assignment of patterns in raw material displacement to one of the models described in Chapter 3, although some elements might be discernible. Ethnographic studies have clearly demonstrated that many scenarios can exist concurrently, even within the same cultural context. Thus, theoretical models can serve as tools for approximation, but never reconstruct reality.

As such, specific theoretical models can be applied to individual archaeological assemblages, however, they will never encompass the entire material culture – *the interaction between human beings and materials within different social contexts* (Mills & Walker 2008, 3) – of a society. This is even more relevant for the ideological nature of human actions.

Theoretical models dealing with prehistoric and historic raw material procurement patterns are inexhaustible, subject of countless scientific studies and only touched on the surface by the discussion provided in Chapter 3. The impact of the application of natural scientific techniques for raw material provenance studies to theoretical models and social implications will be the gathering of "hard scientific data", minimizing conjecture. This will be useful for both, prehistoric archaeology and historical archaeology with humanistic approaches (e.g., in the case of gunflint production). Providing a solid analytical basis for theoretical models will improve the significance of considerate assessments. This is the most important contribution of the MLA to socio-anthropological science.

7. Summary and conclusion

The case studies presented in the course of this dissertation were aimed at exploring the suitability of the Multi Layered Approach (MLA) for chert source provenance studies in an archaeological context. Three scientific problems were addressed:

1. A differentiation between the Rein Basin (Styria) and the Baiersdorf (Lower Bavaria) chert sources for Palaeolithic and Neolithic stone tool production in Styria.

2. Distinguishing radiolarites from the Northern Calcareous Alps and the Carpathian Mountains and an application to Upper Palaeolithic finds from the Krems-Wachtberg site in Lower Austria.

3. The characterization of French, Polish and Italian flint for gunflint production concerning a gunflint cache from Schloss Neugebäude, Vienna.

Rein versus Baiersdorf chert

Tabular and nodular chert from Styrian Palaeolithic and Neolithic sites was for the longest time thought to originate from either unknown sources in the case of the chert nodules or from the well known Baiersdorf tabular chert source in Southern Bavaria.

In mineralogical literature from the 1970s, a Styrian chert source located at the Rein Basin north of Graz was described. However, the Rein Basin chert deposit was associated with archaeological find material only recently. Since the raw material from Rein and Baiersdorf correspond visually to a very high degree, thorough analytical investigations introducing the Multi Layered Approach (MLA) were conducted in order to find possibilities to differentiate between the raw materials.

The application of microscopical, petrographical (thin sections) and mineralogical (XRD, IR – spectroscopy and SEM-EDX) analysis methods failed in discriminating the sources of Baiersdorf and Rein. Geochemical investigations provided the possibility to clearly differentiate chert from Baiersdorf and Rein by lithium (Li) and boron (B) contents detected

by LA-ICP-MS. The application of the geochemical results to samples from the Repolust Cave and several characteristic chert finds from Styria and Carinthia proved a clear coincidence between data gained from the archaeological material and the Rein data cluster. Thus, an origin of the Middle Palaeolithic assemblage from the Repolust Cave and younger chert tools from the lacustrine Rein Basin chert source could be established.

Concerning the raw material deposit at Rein, these assessments have farreaching implications. Stone tools produced from a nodular chert variety from the Rein Basin at sites of Middle Palaeolithic hunter-gatherer groups (Neanderthals) are evidence of a much earlier utilization of the Rein chert source than previously assumed. The proof of actual mining of tabular chert in Neolithic times in the course of a small scale excavation places the Rein chert deposit on the same level with the radiolarite mining site of Vienna-Mauer, the so far only established Neolithic mining site in Austria (except for "opencast mining" in the Tyrolean Alps). Two Early Medieval strike-a-lights from the same tabular chert give evidence for an occasional usage of Rein raw material beyond prehistory (even it is uncertain if these artifacts are reused Neolithic pieces).

Northern Alpine versus Carpathian Radiolarites

In accordance with previous studies (Elekes et al. 2000; Cheben & Cheben 2010), the currant approach has demonstrated that visual, microscopical and mineralogical-petrographical investigations do not lead to compelling results in the distinction between Northern Alpine and Carpathian radiolarite sources. The potential of the MLA, combining principal methods and aiming to generate a definitive match for each source, eventually became apparent.

LA-ICP-MS geochemical analysis was found to provide a tool for radiolarite provenance studies in an archaeological context. Trace elements barium (Ba), magnesium (Mg) and to a certain degree strontium (Sr), rubidium (Rb) and vanadium (V) produce the most conclusive results for source distinction. A differentiation between Northern Alpine and Carpathian radiolarite sources was possible plotting barium versus magnesium. Nine of the Krems-Wachtberg artifacts could thus be assigned to a northern alpine provenance. These results did not reveal specific source regions within the NCA, because the raw materials were most likely collected from river gravels at the Danube or nearby rivers as indicated by the presence of

cortical remains. Notably, the results prove the presence of high quality radiolarites in the local gravel banks that played an important role for stone tool production during Upper Palaeolithic times in the Austrian Wachau region.

However, one artifact produced strikingly different geochemical results, clearly situating it within the Carpathian data cluster. The data suggest an origin from the White Carpathian Mountains, most likely from a local gravel bank as indicated by remains of the natural (gravel-) surface.

Meusnes, Kraków, Lessini Mountains: The Schloss Neugebäude gunflint cache

Questions concerning a substantial gunflint cache from Schloss Neugebäude in the south of Vienna concentrated on the circumstances of the deposition and – even more important – the identification of the "last holders" of these military supplies. A crucial factor for an assignment of the gunflints either to the Austrian army or to French forces during the Napoleonic period was the provenance of the major component of the cache, consisting of a raw material referred to as "silex blond".

Consequently, raw material analysis was conducted according to the MLA. Visual, microscopical and geochemical investigations using LA-ICP-MS were applied. Trace element concentrations were determined and particularly germanium (Ge) in combination with other elements was established to be best suitable for source distinction. The results revealed the absence of Polish material in the gunflint cache, and proved the origin of all analysed specimens of the "silex blond"-type variety from the Meusnes source in France.

Since Affolters preliminary raw material investigations revealed also mainly sources controlled by the French for the remaining gunflints, a French ownership of the Neugebäude cache is very plausible.

Most likely, Napoleon's troops left the stock behind in the course of their withdrawal from Vienna in 1809. During the war, the French were able to conquer Austrian military equipment, represented by the Lessinian fraction of the gunflints in the cache. After plundering the city, the French army left Vienna, loaded with desirable goods, and certainly not intending to take unnecessary weight back home. The fact that the French were in

possession of the most important source for gunflint production at the time, Meusnes, makes it even more probable that they felt no need to do so. Thus, it can be assumed with high certainty that the French soldiers buried the gunflints in the secluded Löwenhof-area of their war camp, Schloss Neugebäude, in order to make these military supplies inaccessible to their enemies, the Austrian army. Apparantly, they succeeded until the rediscovery in the 20th century.

In conclusion, the case studies presented in the preceding chapters demonstrated the successful application of the Multi Layered Approach using LA-ICP-MS for chert source provenance studies. One clear result arose from the experiences gained in the process of working on chert raw materials: The fundamental research question in archaeological raw material science has to be rephrased. **"Where does an artifact come from"** is not to be answered that easily. Investigations applying MLAS 1 (macroscopic analysis) and MLAS 2 (microscopical investigations) have to be conducted ex ante, reducing the question to the following: **"Does a particular artifact originate from the XY source"**. In most cases, this can be answered by MLAS 3, geochemical analysis.

The work presented here establishes that the MLA is a valid analytical method that can be used to identify the sources of chert and flint artifacts, depending on the data base available. The gathering of solid data will constantly refine the resolution of the MLA, and we have only begun to decifer the "chert-code".

8. APPENDICES

Appendix A: Selected historical references to gunflint production, with special regard to the Austrian Empire

This compendium does by no means make a claim to completeness. Such an undertaking would be impossible, for one due to the inaccessibility of sources buried in countless local archives and private collections, and secondly due to the fact that excerpts from all known sources would make this appendix too extensive to handle.

The selection of material was guided by the following intentions:

Sources cited must be directly linked to the subject. This is in the first place gunflint manufacturing and trade in the Austrian Empire.

The sections concerning the quarrying of the raw material, the production processes and especially economical aspects also encompass regions outside the Austrian territories, such as France and England, because these were the main centres for gunflint production in Europe at that time. For these regions, only the most important primary sources were selected as examples.

Within the sections, the extracts of the literary sources are sorted by numbers (REF 1-59) according to their allocation by region and in chronological order. References cited more than once, additionally have their primary REF-number postpositioned in parenthesis, e.g., REF 21 **(=REF 19)**: Raymond et Roth (1809). Consequently, in the main text of the thesis, primary historical sources contained this Appendix A are cited according to their REF-number (e.g., Appendix A, REF 1).

1. Workshops and raw material for gunflints

1.1. Contemporary Austria

REF 1: Kirnbauer, F. (1964). Der Tiroler Landreim (1558). Wien, 71 p.

Lines 878 – 879:
„Berggrün und Lasur wird gemacht viel.
Die Salzpfanne gibt Kesselbraun subtil.
Zu Feuerbüchsen Sonnwend-Jocher Nieren[45]
Tut man ins weite Land verführen."

REF 2: Reichel, R. (1889). Kleine Beiträge zur Geschichte des steirischen Bergbaus im Zeitalter des österr. Erbfolgekrieges. Mitteilungen des Historischen Vereines für Steiermark 37, Graz, 195-196.[46]

Pg. 195-196:
„Am 22. December 1745 wurde F.[47] aufgefordert zu berichten, in welchem Zustande sich der von einer löblichen Hofkammer und dem Bancalrathe von Bendel angezeigte Flintensteinbruch befinde.
Im Jahre 1738 war der Oberbergrichter mit dem Handelsmann Pietro Bicineli, der Eisenerzer Bürger Hofer und einen Berghäuer an dem Orte; Bicineli liess einige Stufen brechen und mitnehmen, um sie nach Venedig zu schicken. Zu genauerer Untersuchung mangelte die Zeit, da die Bergleute wegen der Härte des Steines eigenes Stahlzeug hätten vorrichten müssen, wozu es einer Frist von 8 Tagen bedurft hätte. Von Eisenerz bis zum Gamsforst seien 6-7 Stunden zu reiten, daselbst wohne ein Admontischer Rucksass, Namens Wickel, über dessen Behausung sei der Flintensteinbruch, in dem der Flintenstein 6 Zoll dick zu Tage stehe. 1741 war der Bergrichter abermals dort, als er bei der französisch-bairischen Invasion den Pass Palfau überwachte, hatte aber damals nur Holzknechte bei sich."

REF 3: Kurrende by Emperor Joseph I. from Austria, September 5, 1787 (collection Esterl, Gleisdorf, Styria):

"Seine Majestät haben allergnädigst zu entschließen geruhet, daß von nunam demjenigen, der in den Erblanden einen bisher noch unbekannten Feuerstein=Anbruch, woraus gute, den französischen gleichkommende Flintensteine erzeuget werden können, zuerst entdecket, einhundert Speziesdukaten, demjenigen aber, der gute und gehörig zugerichtete, den französischen gleichkommende Flintensteine, welche aus einem bisher noch unbekannten innländischen Anbruch verfertiget worden, in gehöriger Quantität, und in der Kontinuazion zu liefern weiß, dreyhundert Speziesdukaten, welche aus dem Militarfond zu bezahlen kommen, zur Belohnung zugesichert werden sollen. Welche mit Hofverordung vom 23. August

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[45] „Sonnwend-Jocher Nieren": The location of the "Sonnwendjoch" is problematic. There are two mountains called "Sonnwendjoch" in the area of Tyrol: "Vorderes Sonnwendjoch", the south-eastern offset of the Rofan Mountains, and "Hinteres Sonnwendjoch", the highest mountain of the Bavarian Prealps. A very similar toponym, "Sonnjoch", refers to a mountain in the Tyrolean Karwendelgebirge. According to T. Bachnetzer, the entire mountain range of the Rofan was called "Sonnwendjoch" until the 19th century.

[46] The original source is not traceable (Klemm 2001, 153-154).

[47] Oberbergrichter Johann Anton Ferch.

hereingelangte höchste Entschliessung zur Allgemeinen Wissenschaft hiermit kundgemacht wird. Graz den 5ten September 1787." (Slotta 1980, 351).

REF 4: Ployer, C. (1800). Ueber die Flintensteinfabrication in Wälsch – Tyrol. Jahrbücher der Berg- und Hüttenkunde 4, 2. Lieferung, 151-160.

Pg. 160:
„Ganz neuerlich ist eine Flintensteinfabrik im Salzburgischen, 2 Stunden von der Hauptstadt, im Hirschsteiggraben des Glasenbacher Thales errichtet worden. Die landesherrliche Verleihung ist vom 4. Jun. 1798. Die Gewerkschaft liefert geschliffene und gehauene Musketen – Flinten – Stuzen – Kugelbüchsen – Pistolen – und Terzerolsteine, grössere und kleinere Schieferstücke für Tobakraucher, größern und feinern Schmirgel."

REF 5: Keess, S. von (1824). Darstellung des Fabriks= und Gewerbswesens in seinem gegenwärtigen Zustande, vorzüglich in technischer, mercantilischer und statistischer Beziehung. Zweyte Ausgabe, Erster Theil. Wien, 621 p.

Pg. 492:
„Nr 24: Feuerstein, ein meist schwarzes, graues, oder bräunliches, in hohem Grade hartes Fossil, welches den Kreidegebirgen eigen ist, wo es in größeren oder kleineren Knollen vorkommt, und welches hin und wieder auch ein Conglomerat (den sogenannten Wurst- oder Puddingstein) bildet. Das erste Muster von dunklerer Farbe ist französischer Feuerstein, das zweyte galizischer. Den letzteren zieht Prof. Hacquet dem französischen vor, und erzählt, daß noch unter Kaiser Joseph II. jährlich 20.000 fl für 10 Millionen Flintensteine aus Österreich nach Frankreich gegangen seyen. In Galizien findet sich der Feuerstein in großer Menge bey Podgorze im Bochnier, bey Brzezany im Brzezaner und Nizniow im Stanislawower Kreise. Auch Tyrol in den südlichen Gebirgen, Steyermark bey Seewiesen, Hiflau sc. besitzen Feuerstein, der als solcher benutzt wird. Er gehört zu den nutzbarsten Steingattungen des Kieselgeschlechts."

REF 6: Kunst= und Gewerbe=Blatt (1835). Herausgegeben vom dem polytechnischen Vereins für des Königreich Bayern, Einundzwanzigster Jahrgang, Dreyzehnter Band, Heft IX, 792 pp.

Pg. 556:
„Am häufigsten und ausgezeichnetsten wird der Feuerstein in dem Muschelkalke und in der Kreide gefunden, als in den Kreidegebirgen Frakreichs, Englands, Spaniens, Dänemarks, der Insel Rügen, Galliziens, Polens, Russlands, der Steiermark, Böhmens, Mährens u.s.w.; ...Im übrigen Teutschland findet man ihn fast überall, wo der jüngere Kalk vorkömmt, so besonders in Tyrol an der Etsch, im Salzbugischen bey Hallein, Kuchel, Lofer, Thal Unken, in der Oberpfalz bey Burglengenfeld in meist sehr großen Knollen (wo selbst eine Feuerstein=Fabrik betrieben wird)."

1.2. Italy

REF 7: Nachricht von den Flintensteinbrüchen bey Avio, in Wälsch Tyrol. Bergbaukunde, Zweyter Band (1790). Leipzig, 383-389.

Pg. 383:
„Die bisher in der Gegend bey Avio bekannten Lagerstätte der Feuerstein befinden sich gleich hinter jetzt genannten Marktflecken, dies- und jenseits der Etsch. Die jenseitigen liegen in den von dem hohen Kalkgebirge, Monte Baldo genannt, entsprungenen, und theils auf das Gehänge desselben aufliegenden, theils weiter herabgeschlemmten Mittel- und Flötzgebirgen, zu beyden Seiten eines ausgerissenen Seitenthals, Vall delle Aque nere genannt…
Die Hügel, worinn die Feuersteine liegen, sind folgende: Costa longa, Gradika, Costone, Tratte Soli, Lawakio."

REF 8 (= REF 4): Ployer (1800).

Pg. 151-153:
„Auf den Montebaldischen Vorgebirgen bei Avio, und auf jenen bei Ala in den gräflich – Castelbarcoischen Gerichten finden sich die Feuersteine in einer selten über 2, bis 2 1/2' mächtigen Schicht von mässig verhärteter Kreidenerde, die das darunter liegende Kalkgebirg bedekt.()
In diesem Kreideflöze sizen die Feuersteine zuweilen in zusammenhangenden, doch sich nicht weit ausdehnenden tafelförmigen Trümern, die sehr flachen Flözlagen gleichen; aber fast nie mehr als 3 bis höchstens 6' von Gebirg auf sich nehmen, und sodann sich auskeilen.
Solche lagerförmig an einander hangende Feuersteine sind nie gut. ()
Meistens liegen die Feuer- oder Flintensteine ½ bis 1 ½' unter der Oberfläche, wo das Kreideflöz vorzüglich mürbe, und zerklüftet ist. Sie bildem am öfteren unordentliche bald mehr, bald minder runde Kugeln, unförmliche hier hökerichte, dort mit Vertiefungen versehene Klumpen und Zaken von verschiedenen Gestalten, deren die grössten selten über einen halben Cubicfuss halten. Am gewöhnlichsten gleichen sie der Grösse einer oder zweyer Mannesfäuste, und ich möchte sie hierwegen sowohl, als besonders in Ansicht ihrer abgerundeten Aussenfläche, und ihrer Lagerstätte fast mit den Engländern Chalkegg, oder Kreide Eier nennen."

1.3. Slovenia

REF 9: Hoyer, J.G. (1804). Allgemeines Wörterbuch der Artillerie, welches die Erklärung aller verschiedenen Kunstwörter, Begriffe und Lehrsätze der Geschützkunst in theoretischer und praktischer Hinsicht, nebst der Geschichte der wichtigsten Erfindungen derselben, enthält, 1.1. (A-J), Tübingen, 274 p. (source not available).

Pg. 98:
Flintenstein.
According to Penz & Trnka (2004, 239, footnote 20), Hoyer mentions gunflint production at Transylavania (Siebenbürgen) and Krain, unfortunately without providing further information.

REF 10: Allgemeine deutsche Real=Encyklopädie für die gebildeten Stände. (Conversations= Lexikon). Vierter Band, Leipzig, 1834, 1050 p.

Pg. 96:
*„Einzeln findet man sie auf der ganzen Erde zerstreut, gewöhnlich aber nesterweise in runden Klumpen von 100 300 Kubikzoll, mit einer Rinde von Kreide, Gyps oder Kalkmergel, in Frankreich, besonders in der Champagne und Berri, von wo aus lange Zeit die einzigen Flintensteine verführt wurden, in Italien, Tirol, Salzburg, auf der Insel Rügen, in **Krain**, Siebenbürgen, Galizien, Podolien und der Moldau.“*

REF 11: Hatle, E. (1885). Die Minerale des Herzogthums Steiermark. Graz, 212 pg.

Pg. 38:
„Hornstein:
Nach Zollikofer: Laisberg bei Cilli und Swetina südöstlich vom Dostberg, schwarzer Hornstein hie und da in Nestern oder dünnen Lagen im Guttensteiner Kalk;“

REF 12: Aigner, A. (1907). Die Mineralschätze der Steiermark. Hand und Nachschlagebuch für Schürfer, Bergbautreibende und Industrielle. Wien – Leipzig, 291 p.

Pg. 41:
Feuerstein:
„Knollenförmiger, oberflächlich mit einer weissen, matten, kalkigen Rinde bedeckter Feuerstein von bräunlichgrauer bis schwärzlichbrauner Farbe ist im Joanneum von Weisskirchen, und vom Lichtenwald an der Save; angeblich findet er sich am ersten Orte in einem Thonlager in Mugeln, und das letztgenannte Vorkommen soll mächtig sein.“

1.4. Hungary

REF 13: J. M. Schweighofers Abhandlung von dem Kommerz der österreichischen Staaten (1785). Wien, 435 p.

Pg. 51:
„Magnete werden in Ungarn gefunden. Die Flintensteine kommen diesen zwar an Vorteflichkeit nicht gleich, an Größe des Nuzens aber, den sie dem Land bringen, und dem Verkehr, so mit selben gemacht wird, übertreffen sie jene noch. Halb Deutschland versorgt sich mit Flintensteine aus Tirol.“[48]

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[48] It is questionable if the text refers to Hungarian or rather to the latter mentioned Tyrolean material.

REF 14: Liechtenstein, J. Freiherr von (1791). Staatsverfassung der Oesterreichischen Monarchie im Grundrisse. Wien, 416 p.

Pg. 54:
„ ...Agat und dessen verschiedene Nuancen fast in allen Provinzen; Jaspis in Krain, Böhmen und Ungarn, Flintenstein im Lande unter der Enns, bessere in Steyermark und Gallizien, dann auch in Ungarn;...“

REF 15: Thiele, J.C. von (1833). Das Königreich Ungarn. Ein topographisch-historisch-statistisches Rundgemälde. Dritter Band, Kaschau, 284 p.

Pg 225:
„Benye, (Erdö), ung. Marktflecken...Die weintragenden Ortsgebiete sind: Tólcsva, Verömaly, Zsabas, Barnamály, Öszvér, Múlato-Hegy und Várhegy. Aus diesen Bergen entspringen unter mehreren anderen zwey Heilquellen, die eine heisst Rednek, und dient als Bad, die andere Szemgyógitó...Auch findet man hier Hornstein, der sich gut spalten lässt, und einen guten Flintenstein abgeben könnte.“

1.5. Austrian Silesia

REF 16: Letter from King Friedrich II from Prussia to general von Linger, 30th July 1751 (original source not available, text adopted from Seel, W. (1981). Flint, Flintenstein, Pierre à Fusil. Die europäische Geschichte eines historischen Rüstungsgutes. Deutsches Waffen – Journal 10, 1453).

„Übrigens werdet Ihr Euch zurückerinnern, wie Ihr Mir vor geraumer Zeit gemeldet habt, daß Ihr durch die Artilleristen Proben machen lassen würdet, ob nicht aus den an verschiedenen Orten in hiesigen Landen und in Schlesien in großer Menge befindlichen feinen Steinen[49], hinlänglich gute Flintensteine zu machen, um deren sich wenigstens zum ordinären Exerciren bediene zu können; da Ich von Euch nachhero nichts weiter desfalls vernommen, als habe Ich Euch daran erinnern wollen, und will Ich Euren Bericht deßhalb noch gewärtigen.“

REF 17 : Weigel, J.A.V. (1804). Geographische, naturhistorische und technologische Beschreibung des souverainen Herzogthums Schlesien. Achter Theil, 259 p.

Chapter „Landesherrschaft Beuthen“, Pg. 216:

> *„1) Quarz, gemeiner,....*
> *2) Hornstein*
> *a) muscheliger, gelblichgrau, in Feuerstein übergehend, in dichtem Kalkstein, zu Tarnowiz bei den Stollenschächten.*
> *...*
> *3.) Feuerstein, in kleinen Lagern, bei Bobrowice.“*

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[49] According to REF 19, von Oeynhausen (1822), the request resulted in at least testing of the raw material.

REF 18: Raymond et Roth, M.M. (1809). Tableau statistique de la monarchie autrichienne, au commencement de la guerre présente. Paris, 157p.

Pg. 68:
„Pierres à fusils, dans la Silésie Autrichienne, et les meilleures dans la Gallicie orientale, près da Podgorze et à Pokuti ; avant de les avoir découvertes, on achetoit annellement un million de pierres à fusil de la France, qui coutoient 20,000 flor."

REF 19: Oeynhausen, C. von (1822). Versuch einer geognostischen Beschreibung von Oberschlesien und den nächst angrenzenden Gegenden von Polen, Galizien und östreichisch-Schlesien. Essen, 473 p.

Pg. 404:
„Häufig kommen auch Feuerstein-Geschiebe vor, namentlich bei Mackau[50] und Krawarn[51]; man wagte hier sogar Versuche auf dieselben[52], es war aber ihr Vorkommen zu sparsam, um eine Feuerstein-Fabrik anzulegen."

1.6. Galicia

REF 20: Hacquet, B. (1792). Physische und Technische Beschreibung der Flintensteine, wie sie in der Erde vorkommen und dessen Zurichtung zum ökonomischen Gebrauch, sammt Abbildung der dazu gehörigen Werkzeuge. Wien, 1792, 64 p.

Pg. 27-28:
„Erstens: ()
Diese Flintensteinkugeln, welche von ein bis 200 lb. Schwere vorkommen, sind inwendig meistens schwarz, und bestehn aus unfühlbaren Theilen, auswendig sind sie mit einer weissen, dem feinen Postpapier gleichen Rinde umgeben, oder welches doch selten geschieht, fehlet sie wohl auch ganz und gar. Obwohl die Gestalt dieser Steine meistens rund ist, so sind sie doch manchmal auf eine etwas abweichende Art gebildet, als länglich rund mit einem Wirbel oder Knöpfchen, so wie eine Citrone versehen, welche Erhabenheit oft von dem Arbeiter Knorbel genannt wird; oder ganz rund und einfärbig, welche letztern die beste Zurichtung leiden,"..()

Pg. 32:
„Viertens von einem halben bis zu einem ganzen Schuh lange, und einige bis zween Zoll dicke, runde priopolitenförmige Flintensteine, von Farbe grau schwarz und ganz dicht. () Diese lassen sich wegen ihrer Dichtigkeit ganz gut zu Flintensteinen zurichten."

Pg. 39-40:
„Siebentens ein hornartiger, oder gelb durchsichtiger Flintenstein, welcher von weicherem Bestand ist, als der vorhergehende. ()
Diess ist eigentlich der gemeine Flintenstein, der über den Podhorcefluss bei Zbrycz in der Republik Pohlen sehr selten in Gallizien so weit bis die Stunde der Entdeckungen davon gemacht worden, England und anderen Orten bricht..()

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[50] Mackau: The village Makau/Maków in the Voivodship Silesia, Poland.
[51] Krawarn: Kravaře (Deutsch Krawarn), village in the region Moravian Silesia (Moravskoslezský kraj).
[52] Compare REF 16, Seel (1981).

Diese Abart von Flintenstein ist beinahe jederzeit mit einer Zoll dicken, weissen Gibsmergelrinde überzogen, so wie sie zu Podgorce, vor Krakau am Weichselfluss in Gallizien, in nicht hellen sondern grau – hornfärbigen Kugeln brechen; welche sich zum Gebrauch tauglich befinden, und man auch alldorten schon seit ein paar Jahren sie auf Flintensteine bearbeitet."

REF 21 (=REF 19): Raymond et Roth (1809).

Pg. 96:
„La fabrique de pierres à fusil à Brzeznan, dans la Gallicie oeientale, fournit toute l'armée. Autrofois on les importoit de France, à laquelle on payoit 20,000 flor pour cet article."

REF 22: Bredezky, S. (1811). Reisebemerkungen über Ungarn und Gallizien. In II Bänden, 1809, in: Annalen der Literatur und Kunst in dem Oesterreichischen Kaiserthume, Jahrgang 1811, Erster Band. Wien, 416 p.

Pg. 62:
„V. Krzeszowice. VI. Jaworsno. Hier sind gute mineralogische Beschreibungen des Badeortes Krzeszowice und des Steinkohlenbergwerkes Jaworsno und Krzeszowice. Unweit Krakau hat der Eigenthümer des Sperlingischen Bergwerkes einen Kalkofen errichtet; dabey ist die Flintenstein=Fabrik des Herrn Bergraths Vampe."

REF 23 (=REF 19): Oeynhausen (1822).

Pg. 266:
„Auch in technischer Hinsicht sind diese Feuersteine nicht unwichtig. Bei Morawice, zwischen Krakau und Alwernia, ist schon seit längerer Zeit eine nicht unbeträchtliche Feuerstein=Fabrik, wo sehr gute Flintensteine gearbeitet werden; und leicht würden sich diese Fabriken noch vervielfältigen lassen."

REF 24: Thielen, M.F. (1827). Alphabetisch – topographisches Postreise-Handbuch für den Oesterreichischen Kaiserstaat. Wien, 358 p.

Pg. 177:
„Nizniow, Markt in Galizien, im Stanislawewer Kreise am Dniester. Sie hat eine Flintenstein-Fabrik die jährlich bey 2,000,000 Feuersteine erzeugt, und das Material dazu von Mariampol bezieht."

1.7. Transylvania (Siebenbürgen)

REF 25 (=REF 20): Hacquet (1792).

Pg. 2:
„Frankreich, England, Galizien, Siebenbürgen, Tyrol, usw. besitzen dergleichen Steine, welche bald in schichten Lagen nicht sehr tief unter der Erde liegen, wie in der Grafschaft oder Gouvernement Berry in Frankreich, bald etwas zusammengehäuft in Vorgebürg wie in

Valle Produluï, in Zarander Komitat[53] *in Siebenbürgen, wo in dem oder Salbänder dieser streichende oft Jaspis und karneolartiges Gestein mitführt, der in ihrem Märgel oder Kreidenlag wie die Achatkugel bei Utzenbach, Oberstein in Zweibrükischen so in Galizien die Flintensteine, wo sie dann von den kleinen Bächen und Flüssen, als der Prut in der Hottiner Raya oft herausgeschwemt, und am Tag gefunden werden."*

Pg. 20-21:
„Ist der Stein rund, so brechen seine Splitter mehrschalicht, so wie die Schichten eines Zwiebel, ist er plat oder halbrund, viereckiht wie in dem erwehnten Zarander und Hunyader Commitat in Siebenbürgen man das Beyspiel hat, so haben auch die Splitter weniger Gewölbung, folglich weniger geschickt sich bearbeiten, zu lassen."

REF 26 (=REF 9): Hoyer (1804).

Pg. 98:
Flintenstein.
See REF 8, Siebenbürgen.

REF 27 (=REF 10): Real=Encyklopädie (1834).

Pg. 96:
„Einzeln findet man sie auf der ganzen Erde zerstreut, gewöhnlich aber nesterweise in runden Klumpen von 100 300 Kubikzoll, mit einer Rinde von Kreide, Gyps oder Kalkmergel, in Frankreich, besonders in der Champagne und Berri, von wo aus lange Zeit die einzigen Flintensteine verführt wurden, in Italien, Tirol, Salzburg, auf der Insel Rügen, in Krain, **Siebenbürgen***, Galizien, Podolien und der Moldau."*

2. Raw material exploitation

2.1. France

REF 28: Gillet-Laumont, F.P.N. (1798). Extrait d'un Mémoire du citoyen Salivet, sur la fabrication des pierres à fusil dans les départements de l'Indre et de Loir-et-Cher. Journal des mines, 1796-1797, vol. 2, no. XXXIII, an V, 713-722.

Pg. 714-716:
„Les ouvriers caillouteurs sont rarement propriétaires ; mais ils s'associent cinq ou six et achètent le droit de fouiller sur environ un demi-arpent qu'ils payaient, vers le milieu de l'an 2 ,400 à 520 francs. Ils exploitent la couche de cailloux propres à faire des pierres à fusil , par des excavations horizontales, à la profondeur d'environ 16 mètres (près de 50 pieds) dans lesquelles ils descendent par plusieurs petits puits disposés en gradins, que l'on appelle carrières, caves ou crocs.
Ils commencent par creuser dans un terrain ordinairement sablonneux(), une large excavation à-peu-près ronde, de 13 à 16 décimètres (4 à 5 pieds) de profondeur: étant alors parvenus dans un terrain plus solide , ils ouvrent dans ce trou un puits de forme

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[53] Hungarian *Zaránd*, romanian *Zărand,* former hungarian Komitat, since 1870 part of the Arad and Hunyad Komitat, most important town were Körösnánya, Nagy-Halmágy and Brád. Nowadays it belongs to Romania, kraj Arad.

rectangulaire, de 16 à 20 décimètres (5 à 6 pieds) de longueur , sur 7 (2 pieds) de largeur, et ils le creusent de 30 à 32 (9 à I0 pieds) de profondeur.

Ils font ensuite un second puits de pareille dimension , mais non à l'aplomb du premier ; pour cela ils pratiquent horizontalement, à la profondeur de 6 à 7 décimètres (2 pieds) sur toute la longueur d'un des côtés longs du premier puits une espèce de niche ceintrée : c'est à cet aplomb qu'ils foncent leur second puits , de la même profondeur que le premier. Ils en creusent de même un troisième , puis un quatrième , s'il est nécessaire, pour parvenir au lit de cailloux propres à être taillés.

Lorsqu'ils y sont arrivés , ils s'étendent horizontalement par des galeries très-basses,, où ils travaillent à genoux ; ils les disposent en rayons partant du puits comme centre , et les prolongent autant, que la lumière peut y brûler, le plus souvent sans s'embarrasser s'ils sont hors des limites du terrain où ils ont acquis le droit de fouiller ; ensuite ils font des ouvertures d'une galerie à l'autre , en laissant d'espace en espace quelques piliers pour soutenir le plafond.

Ils sortent tous les cailloux avec beaucoup de célérité , en se les jetant de mains en mains sur les cinq ou six repos formés par le fond des puits, disposés en gradins. A l'égard de la terre, ils ne sortent que celle des premières galeries , et remplissent successivement les anciennes excavations avec la terre des nouvelles."

2.2. England

REF 29: Skertchly, S.B.J. (1879). On the Manufacture of gun-flints, the methods of excavating for flint, the age of Palaeolithic man, and the connection between Neolithic art and the gun-flint trade. Memoirs of the Geological Survey. England and Wales. London, 80 p.

Pg. 21-22:
"Method of digging.
Division of labour finds no adherents among flint-diggers, each of whom sinks his own pit and raises his own stone; the only aid being the occasional employment of one or two boys, generally the children of the workmen. Two reasons are assigned for this individuality of effort, namely, that the demand is not great enough or sufficiently regular to pay for the use of expensive plant; and secondly, there is much difference in the paying value of the pits, some yielding four or five jags of stone per week while others only yield two or three; hence there is some degree of speculation in the work, and each man hopes to pitch upon a valuable take. When a man is about to sink a pit he takes into consideration the chance of obtaining good stone in plenty, the depth to which he will have to sink, the dryness and warmth of the situation, and the proximity of new or old workings. Of these, the depth is considered perhaps the least, as the quality and quantity of the stone is the most, important. Some men are particular in choosing a take among trees, because the chalk is then drier, and the shelter of the wood diminishes the chance of the workman taking cold when coming up heated to the surface. The proximity of old workings is avoided from the uncertainty of the extent of their burrows, which might seriously diminish the value of a pit, but when very good stone is believed to have been obtained new pits are sometimes sunk among old ones. Pits are often sunk near together, especially in summer time, when the air is sometimes bad, and the workings are made to communicate, so that a draught is obtained through the two shafts. The extent of the workings is determined by the labour required to carry out the stone got in a day; they seldom run more than 12 yards in one direction.

The average time taken to sink a pit of about 30 feet is three sleeks, or 10 feet per week, and some of the more careful men commence a new shaft before an old pit is worked out in order to have some money coming in all the time. The pits are worked all the year round.
A digger selects a spot to sink a pit upon, and sets four pieces of chalk, or digs up four sods, at the corners as his "marks," which marks are held sacred and may remain for years before the pit is sunk. No digger may have more than one set of marks be-sides his pit; but he may have two pits and a set of marks at one time, and if he clears out the first stage of a new pit that counts as one, though it may not be sunk further for months or even years. Thus a digger can have a pit at work, one begun, and a set of marks. ()"

2.3. Italy

REF 30 (=REF 7): Bergbaukunde (1790).

Pg. 384:
„Auf den übrigen 3 Orten dieses Gebirgs, findet man nur Findlinge, und im Lavakio d'ala, und dem jenseitigen Hügel, finden sich die, als beste anerkannten Caffé- und schwärzlichbraune Feuersteinkiesel; es ist aber von solchen eben keine ordentliche Lage bishero entdeckt worden, sondern es haben die Rudarischen Arbeiter[54] bishero von solchen nur auf den Alpgräsern die Findlinge zusammen gesucht. Es wollen die Alpinhaber allda (wie die Rudarii sagen) durchaus nicht graben lassen, und wird denen Arbeitern mit dem Tode gedroht."

Pg. 388-389:
„()..so folgt von selbst, dass der Arbeiter die wohlfeilste Gewinnung erwählt, und die nöthigen Stücke zu Lieferung feiner Quantität Feuersteine, um auf einen competenten Lohn zu kommen, so viel und so er kann, auf der Oberfläche zusammensucht, oder höchstens nur aus den obersten Flötzlagen unter der Dammerde nimmt, und da diese bishero noch genug mit Kieseln versehen ist, aller tiefern, kostbaren und beschwerlichen Arbeit, noch mehr aber einer Untersuchung zu Herstellung gewisser und dauerhafter Steinbrüche ausweichet.
Auf solche Art ist bishero neben Zusammensuchung der ledigen Findlinge, nur an verschiedenen, weit von einander zerstreuten Orten, die Oberfläche und Dammerde dieser Gebirge aufgeschürfet, etwan die oberste Geschiebe Flötzlage allein, oder wenn eine zweyte gleich darunter war, auch diese 4 bis 5 Klafter in der Länge entblösset, und die tauglichsten Kiesel herausgenommen; sobald aber die Arbeit über ¾ oder höchstens 1 Klafter tief geworden ist, wieder verlassen, und wegen dem Viehaufftrieb wieder zugefüllt worden."

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[54] There are two possible interpretations:
1.) Chelidonio (2006, 6) states*: "...delle officine di Pian della Cenere, sopra Avio/Monte Baldo, gestite dalla famiglia **Rudari** già dal 1755)"* (...workshops at Pian delle Cenera, ahead of Avio/Monte Baldo, operated by the family **Rudari** since 1755).
2.) Rudari: According to Leschber (2008, 338-339), the *Rudari* are Roma originating from Romania. They were forced to work as miners – traditionally as gold washers – under slave-like conditions until 1864. Most of the Rudari residing outside Romania left after the abolition of slavery in the last third of the 19th century, however some groups fled as early as the 18th century. These people survived conducting basic work, mainly connected to mining activities.
Both considerations could apply to REF 30, however 1.) seems more likely.

REF 31 (= REF 4): Ployer (1800).

Pg. 156:
„Die Prüfung der Steine ihrer Brauchbarkeit halber, sogleich auch die Abförderung der schlechten, geschieht sogleich auf den Bergen, wo sie aus dem Kreidelager mittelst des einzigen Werkzeugs () ausgegraben werden. Dieses besteht an dem einen Theile in einer Rasenhaue, an dem andern hingegen in einem Pikel, und dienet folglich zum Hauen, und Wegräumen, und als Brechhebel zugleich."

2.4. Galicia

REF 32 (=REF 20): Hacquet (1792).

Pg. 26:
„In Galizien hat man noch nicht diese Schichtenlagen wie in Frankreich und England aufgedeckt, aber es ist doch zu hoffen, wenn man dem Werk mit mehreren Betrieb zusetzt, dass man eben diese Lagerstädte finden werde. Man hat auch hier zu Lande die Aufarbeitung dem gemeinen Landmann überlassen…()"

Pg. 44-45:
„Die Flintensteine, welche die Arbeiter hier, so wie in anderen Ländern am Tag finden, sind selten, oder wohl gar nicht zum Zurichten für Büchsensteine tauglich, sie dienen aber weiter zu nichts, als dass sie die Anzeige geben, dass auch solche Steine in der tiefe stecken mögen. Auf diese Anzeige wird hier zu Lande, so wie anderwärts der Boden aufgeschürft, umgewühlt, oder so weit Vertieffungen in die Erde gemacht, als der Arbeiter mit Nutzen und Sicherheit sich mehr oder weniger tief unter die Oberfläche der Erde einlassen kann. Keine ordentlichen Gesenke oder unterirdische Seiten Ausweitung werden hier auf diese Steine so wie z.B. in Berryischen in Frankreich gemacht werden, nicht vorgenommen. Die frisch ausgegrabene Steine werden alsobald bearbeitet, aber dazu dürfen auch nicht zu nass sein…()
Am tauglichsten sind sie, wenn sie nicht lange vor der Bearbeitung aus der Mergelerde genommen werden…()…und so haben die runden vor allen übrigen gebildeten bei der Arbeit den Vorzug…"

REF 33: Hacquet, B. (1806). Bemerkungen über die Entstehung der Feuer- oder Flintensteine, in: Gehlen, A.F. (ed.), Journal für die Chemie und Physik, 1. Berlin, 89-118.

Pg. 93-94:
„Die Gewinnung oder Ausgrabung dieser Steine unterliegt keiner großen Schwierigkeit, da jederzeit die Decke, oder der Boden über denselben, locker ist, und man nichts als Krampen, Schaufeln und Spitzhaken bedarf, um ihr Lager zu entblößen, und sie mit dem letzten Werkzeuge heraus zu nehmen. Sie liegen meistens, wenn sie im Muttersteine nicht festgewachsen sind, wie platt gedrückte Kugeln, selten Schuh dick, aber meistens neben einander, in der weißen oder grauen Mergelerde. Der Landmann liefert solche für drei oder mehr Gulden den Korec (Korez) oder das rheinländische Malter zur Fabrik. Es geschieht hier selten, daß man die Steine an dem Findorte in Schiefer oder Schuppen aufarbeitet, denn da die kalte Jahreszeit in den nördliche Ländern zu lange anhält, folglich der Schnee im Gebirge spät weggeht, so ist es vortheilhafter, in den wenigen Sommermonaten das Material unter Dach zu bringen, und es dann dort, wo geheizt werden kann, im Winter zu verarbeiten. Die

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Methode, die Gruben anzulegen, um die Steine zu gewinnen, findet man auf dem Titelkupfer abgebildet. ()
Die Gruben sind viereckige Löcher von einer bis zwei Klaftern im Durchschnitte. Da die Steine in einer geraden Linie fortreichen, so bleibt von einer Grube zur andern eben so viel Zwischenraum unaufgewühlt, wo also die Arbeiter der Gruben () die Steine aus den gelassenen Zwischenräumen herausholen. Da die Decke durch die Wurzeln des oft darauf befindlichen Gesträppes, u. dergl., gebunden ist, so hält sich das Erdreich gegen den Einsturz, um so mehr, da die Last desselben geringere ist."

REF 34 (=REF 19): Oeynhausen (1822).

Pg. 266-267:
„Die zu verarbeitenden Feuersteine werden in der Nähe von Morawice in 2 - 3 Lachter tiefen Schächten (Duckeln), aus dem aufgeschwemmten Gebirge gegraben, wo sie als Geschiebe sich in sehr großer Menge finden. Ihre Farbe ist gelblich, sie sind halb durchsichtig, und dürfen nicht lange nach dem Ausgraben liegen bleiben, oder müssen doch wenigstens an feuchten und dunkeln Orten aufbewahrt werden, damit sie die Feuchtigkeit nicht verlieren, welche sie zur Verarbeitung geschickt macht."

3. Technology of gunflint production

3.1. France, Meusnes

REF 35 : Anon. (1738). Histoire de L'AcADédmie Royale des Sciences. Paris, 410 p.

Pg. 38 :
„Les Paroisses des Meunes & de Couffy dans le Berry à deux lieues de St Aignan, & à demi-lieue de Cher vers le Midi, sont les endroites de la France qui produisent les meilleures Pierres à fusil, & presque les seules bonnes. Aussi en fournissent non seulement la France, mais allés souvent les Pays étrangers. On en tire de là sans relâche depuis longtemps, peut-être depuis l'invention de la Poudre, & ce Canton est fort borné. Cependant les Pierres à fusil n'y manquent jamais, dès qu'une Carriére est vuide, on la ferme, & plusieurs années après on y trouve des Pierres à fusil comme auparavant. Voilà ca que M. Le Comte de Biévre, qui avoit tout observé sur les lieux & assés long-temps, avoit écrit dans une Lettre que M. D'Isnard sit voir à l'Academie. Les Carriéres & les Mines épuisées se remplissent donc de nouveau, & sont toujours sécondes, comme le concluoit l'Auteur de la Lettre."

REF 36: Hannoverisches Magazin 10, 1772. Hannover, 1773 (original source not available, citation after Förtsch, O. (1892). Gewinnung und Verarbeitung des Feuersteins in England, in: Luedecke, O. (ed.), Zeitschrift für Naturwissenschaften 65, 371-378).

Pg. 373-374:
„Der Feuerstein liegt in dem französischen Gebirge gangweise wie der Schiefer. Hirten und andere dergleichen sonst unbeschäftigte geringe Leute wissen die Feuersteine, ohne viele Umstände, mit einer ganz besonderen Fertigkeit zu spalten und zu schlagen, dass sie die gewöhnliche Form der Flintensteine erhalten. ()

Das aber weiss ich von sicherer Hand, dass man in hiesigem Land[55] im Jahre 1727 einige Constables erstgedachtes Steinschlagen auswärts besonders wirklich hat lernen lassen. Feuersteine aber, die man in hiesigen Gebieten findet, liegen am Tag herum, sind wirbelicht und wollen sich nicht spalten lassen."

REF 37: Johann Karl Gottfried Jakobssons technologisches Wörterbuch, Teil 1. Berlin – Stettin 1781, 816 p.

Pg. 750:

„Soviel man hat erforschen können, giebt es zwey Arten, nämlich von Feuer= oder Hornstein, und von Achatstein. Die erstern kommen, soviel man izt weiß, größtentheils aus der Picardie und Champagne in Frankreich, welche Gegenden die europäischen Kriegsheere hiemit versorgen. Feuersteine von Achatstein schneidet man unter anderem in Nürnberg, wiewohl diese Manufaktur in hiesigen Gegenden noch nicht gehörig bekannt ist, und gedruckte Nachrichten hievon hat man gleichfalls nicht ausfindig machen können. Daher rückt man dagegen folgende historische Nachrichten ein, die dem Herausgeber von dem Hrn. Kriegsrath Richter in Potsdam ertheilet sind. Der vorige König von Preußen, Friedrich Wilhelm, trug dem damaligen Unternehmer der einheimischen Gewehrfabriken, dem verstorbenen Kaufmann Splitgerber auf, die Bereitung der Flintensteine insgeheim in Frankreich erforschen zu lassen. Splitgerber schickte dieserhalb einen Büchsenschäfter der Gewehrfabrik zu Potsdam, Namens Matthias Klose ab. Dieser Mann, der aus Lüttich gebürtig ist, trat 1722 in königl. Dienste, und lebt noch izt als ein Greis von 75 Jahren. Klose begab sich dieserhalb nach St. Anges, einem kleinen Städtchen in dem Gouvernement Berry, wo ansehnliche Flintensteinbergwerke sind. Bey Lebensstrafe darf aber kein Fremder diese Bergwerke sehen. Er weiß also nur soviel, daß die dasigen Hornsteine in einer Kreidemutter liegen, und auf gewöhnliche bergmännische Art in den hohen Gebirgen gewonnen und gefördert werden. ()

Klose arbeitete ¼ Jahr bey einem an gedachten Ort ansessigen Landsmann als Büchsenschäftergeselle, und erlernte auch glücklich die Handgriffe der Flintensteinspalterey. Erbrachte einen 6 Pfund schweren Stein mit aus St. Anges, und machte daraus im Land Flintensteine, welche auch die Probe aushielten.
Nachher mußte er gleichfalls Flintensteine aus einheimischen Feuersteinen verfertigen, und diese fand man in Spessenberg bey Neustadt, Eberswalde in Mittelmark. Er verfertigte die Steine mit Glück, und es wurden hiemit Proben angestellet, sie zersprangen aber nach dem zweyten Schuß, und die ganze Sach gerieth darüber ins Stecken. Die Handgriffe beym Bearbeiten der Feuersteine, sind kürzlich diese. Vermittelst eines stählernen Werkzeuges wird der Stein erst mit der Faust stückweise abgeschlagen und gespalten. Denn er ist schieferich und splitterich. Mit einem andren stählernen Werkzeuge schlägt man ihn zu seiner gewöhnlichen Gestalt, und er geht überdem noch zey bis drey Mal durch die Hände, je nachdem er sich leicht oder schwer bearbeiten lässt. Durch das Sortieren entstehen drey Arten Steine, Pistolen= Flinten= und Batteriesteine, die man ungezählt in Tonnen packt und hierinn verkauft. ()

Ein Werkmeister an der Gewehrfabrik in Potsdam hat auch die Flintensteinschneiderey in Nürnberg gesehen, wo der Achatstein nach Art der Edelgesteine geschnitten wird. Der Mann heißt Mader, man hat aber noch nicht Gelegenheit gefunden, sich näher zu erkundigen. Ergibt sich diese, so wird man die eingegangenen Nachrichten in den Zusätzen mittheilen."

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[55] Consequently Hannover.

REF 38: Hacquet, B. (1789). Beschreibung und Abbildung der Werkzeuge womit die Flintensteine zu Muene in dem Gouvernement Berry in Frankreich und anderwärts verarbeitet werden, in: Höpfner, D.A. (ed), Magazin für die Naturkunde Helvetiens, Band 4. Zürich, 526-542.

Pg. 534-540

„Bevor ich nun von der Bearbeitung dieser Steine zum Mechanischen Gebrauch Erwähnung thue, so will ich erst bestimmen, wie ein gut zugerichteter Buchsenstein eingetheilt wird. Man kann füglich einen solchen durch die Kunst gebildeten Stein in 6. Flächen theilen.

Erstens aus zwey beynahe ebensöhlige Flächen, nemlich eine obere welche schmal und nur meistens 1/3tel des Steins einnimmt und die Rippe der Rücke der Haft (la manche) genannt wird. Dieser Theil des Steins wird von dem beweglichen Theil des Hahnens am Flintenschloß gehalten

Zweytens, die untere Fläche, welche die größte am ganzen Stein, ist meistens etwas ausgehölt, und auf dem unbeweglichen Theil des Hahnens ruht.

Drittens, auf dem obern Theil des Steins kommen zwey schieffe Flächen vor, wovon eine immer grösser ist als de andere, und 45 Grad haben. Die breite oder die schärfeste (le tranchant) ist jene womit Feuer geschlagen wird, sie wird auch von den Franzosen Bord de platine genannt, wenn diese beyde Seiten an einem Stein bleiben, so heißt er Doppelstein 8boucaniere à deux bouts,) wird aber die schmale Seite wie gewöhnlich geschiehet zugerundet, so heißt dies der Kopf (le cul.)

Viertens sind an dem Stein zwey grad oder halbrund ablaufende Flächen, oder die Kanten, les Bords, welche gerade oder halbrund zugerichtet werden.

Zu der Zurichtung der Flintensteine gehören folgende Werkzeuge:

Erstens, ein stumpfer oder Bruchhammer Marteau cassant (); hat an Gewicht gegen 2 Pfund.

Zweytens, ein Spitz- oder Schiefer=Hammer Marteau à pointe (), so scher wie voriger.

Drittens, der Scheibenhammer (), wiegt ein viertel Pfund.

Viertens, das Meissel, Ciseau, welches an beyden Enden Schärfe hat, und an Gewicht ein halb Pfund, und etwas darüber ().

Fünftens, eine gemeine Stahlfeile, um dem Meissel die Schärfe wieder zu geben, wenn es in währender Arbeit abgenutzt wird.

Diese vier ersten Stücke () müssen aus halb Eisen und Stahl bestehen.

Zuerst wird das Meissel oder doppeltes Stemmeisen in einem 1 ½ Schu hohen Klotz, Table de Boucaniere, an den Rand befestiget, solchergestalten, daß die Hälfte dieses Werkzeugs mit einem scharfen Ende eingelassen oder verborgen ist.

() Um einen solchen Klotz können jederzeit drey solche Meißels angebracht werden, um daß eben so viel Steinzurichter darum arbeiten können.

Wenn man nun zur Arbeit schreiten will, so müssen, wie oben gesagt worden, die Klöze oder Steinkugeln, die von 1 Pfund bis zu drey Zentner schwer gefunden werden, die gehörige Tröckne haben; ()

Ist der vorhabende Stein des Zurichtens fähig, so wird, wenn er nicht zu groß ist (die grossen von 1 und mehr Zentner werden, von mehreren Menschen in die Höhe gehalten und mit einem Hammerschlag gespalten) () mit dem stumpfen oder Bruchhammer, ein Anbruch, oder ein paar Zoll grosses Stück von dem ganzen abgeschlagen. ()

Nach diesem wird

Zweytens der Bruchhammer weg gelegt, und wird dafür der Spalt- oder Spitzhammer in die Hand genommen () um damit den Stein in länglichen Schieferstücken zu zersetzen. ()

Wenn man einmal mit dem Schieferschlagen angefangen hat, so muß beobachtet werden, daß der Spitz des Hammers, welcher etwas breitschneidig ist, nur so weit von dem Rand in den Stein eingesetzt wird, als man willens ist grössere oder kleinere Steine zu machen; ()

Bey dem Schieferschlagen oder abhauen, muß man jederzeit in Rücksicht haben, wo man mit dem Hammer einhauen soll, um damit der Schiefer so ausfalle daß er in der Mitte eine Ripe erhalte ().

Da man aber in der Arbeit nicht so genau Acht hat, ob man 2. oder 3. und mehr Linien tief in den Stein einhackt, so pflegt man meistens ohne Rücksicht der Dicke Schiefer zu schlagen, welche beym Zurichten nach verhältnißmäßiger Dicke bald zu Pistolen oder Flinten-Steine gebildet werden. ()

Drittens, die Zurichtung der Steine aus den geschlagenen Schiefers geschieht nun folgends: Der Arbeiter setzt sich auf einen Stuhl, daß er mit seinem linken Knie die Höhe des halbhervorragenden Stemmeisen oder Meißel erreicht, welches vor seiner in dem Klotz oder erwähnten Tisch zu Zurichtung der Flintensteine befestigt ist.

Nun nimmt er in die linke Hand ()einen von denen erwähnten Schiefers und hält ein End davon so breit über die Schneide des Meissels, als er einen breitern oder schmälern Stein zu machen im Sinn hat ().

Nun giebt er mit seinem Scheiben=hammer der mit einem runden Stiele versehen ist, zwey drey oder mehr gelinde Schläge auf den Stein, der auf der Schneide des Meißels gehalten, um daß er von unten auf angeschnitten wird; so bald dies geschehen, hält der Arbeiter den Schiefer von dem Stemmeisen in die Höhe, und schlägt mit dem Hammer daran, wo dann das angeritzte Stücke abspringt: und so fährt er so lange fort, () bis er alle seine Schiefers in beynahe viereckige Stücke zersetzt hat ().

Viertens; nun wird die letzte Hand angelegt den Stein vollkommen zu bilden. Diese gemachte irregulaire Vierecke, werden nun wieder eine um die andere in die Hand genommen, um den Haft zu bilden, das heißt der schlechteste oder kürzeste scharfe Rand, wird zugerundet um den haft zu machen."

REF 39: Dolomieu, D. de (1796). Sur l' art de tailler les pierres à fusil (silex pyromaque). Journal des mines, 1796-1797, vol. 1, no. XXXI, an V, 693-712.

Pg. 706-707 :

„Les instruments qui servent au caillouteur à façonner la pierre à fusil se bornent au nombre de quartre.

1° Une petite masse de fer à tête carrée (pl. XXIII, fig. I), dont le poids ne surpasse pas deux livres (environ un kilogramme), et peut-être moitié moindre, avec un manche de 7 à 8 pouces de longeur; (16 à 20 centimètres) on emploie point l'acier à cet instrument parce que trop de dureté rendrait les coups trop secs et leur ferait fendiller le caillou lorsqu'on l'emloie à le rompre.

2° Un marteau à deux pointes, auquel la position des pointes de percussion donne beaucoup de coup; ce marteau qui doit être de bon acier trempé n'a pas un poids qui passe 16 onces (5 hectogrammes environ) et peut-être moindre, jusqu'a 10 onces (3 hectogrammes environ), il est monté sur un manche de 7 pouces (19 centimètres environ) de longueur, qui le traverse de manière que les pointes du marteau se trouvant plus rapprochées de la main de l'ouvrier que le centre de gravité de la masse; la forme et la grosseur des marteaux des différents caillouteurs varient un peu, mais cette disposition se retrouve dans tous et c'est à elle qu'est due la force et la certitude de son coup.

3° Un petit instrument nommé « roulette » qui represente une petite roue pleine, ou un segment de cylindre de 2 pouces 4 lignes (63 millimètres) de diamètre et de 4 lignes (9 millimètres) d'épaisseur, son poids ne surpasse pas 12 onces (36 décigrammes environ), il est

fait d'acier non trempé et il est adapté un petit manche de 6 pouces (16 millimétres) de longueur qui le traverse par un trou carré en son centre.

4° Un ciseau double, taillé en biseau des deux côtés, semblable à un fermoir de menuisier, long de 7 à 8 pouces (19 à 20 centimètres), large de deux pouces (54 millimètres) d'acier non trempé; par sa pointe il s'implante dans un bloc de bois qui sert en même temps d'établi à l'ouvrier et en ressort de 4 à 5 pouces (11 `13 centimètres).

A ces quatre instruments on peut joindre une lime pour aiguiser de temps en temps le cisseau."

Pg. 707-709 :

„*Procédés.*

Après avoir fait choix d'une bonne masse de silex pyromaque , on peut diviser toute l'opération en quatre temps.

Rompre le bloc.

L'ouvrier, assis à terre , place le caillou sur sa cuisse gauche , et frappe dessus de petits coups avec la masse, pour le diviser en plus ou moins de parties à raison de sa grosseur , et en avoir des morceaux d'une livre et demie à-peu-près (15 hectogrammes) de poids , avec des surfaces larges, dont les cassures soient à-peu-près planes; il tâche de ne pas fendiller ou étonner le caillou par des coups trop secs ou trop forts.

II.' Fendre le caillou ou l'écailler.

La principale opération de l'art est celle de bien fendre le caillou , c'est-à-dire , de lui enlever des écailles de la longueur, grosseur et forme qui conviennent ensuite pour en faire des pierres à fusil ; c'est celle qui demande le plus d'adresse et la main la plus sûre.

La pierre n'a point de sens particulier pour sa cassure , et s'écaille également dans toutes les directions.

L'ouvrier tient le morceau de caillou dans sa main gauche , non soutenue.

Il frappe avec le marteau au bord des grandes faces produites par les premières ruptures , de manière à enlever l'écorce blanche de la pierre , en petites écailles , et à mettre à découvert le silex (); et ensuite il con-tinue à enlever d'autres écailles où le silex est pur.

Ces écailles ont à-peu-près un pouce et demi (4 centimètres) de largeur, deux pouces et demi (8 centimètres) de longueur, et deux lignes (4 à 5 millimètres) d'épaisseur dans le milieu. Elles sont légèrement convexes en dessous , et elles laissent par conséquent dans le lieu qu'elles occupaient, un espace légèrement concave , termine longitudinairement par deux lignes un peu saillantes , à-peu-près droites ( ). Ces sortes d'arêtes , produites par la rupture des premières écailles, doivent se trouver ensuite vers le milieu des écailles enlevées subséquemment; et les seules écailles où elles se trouvent peuvent servir à faire des pierres à fusil.

On continue ainsi à fendre ou écailler la pierre en différens sens, jusqu'à ce que les défectuosités naturelles de la masse rendent impossibles les cassures que l'on exige, ou que le morceau se trouve réduit à un trop petit volume pour recevoir les petits coups qui forcent le silex à éclater. "

Pg. 709 :

„*III.ᵉ Faire la pierre.*

On distingue dans la pierre à fusil cinq parties (fig. 7).

I.° La mèche , partie qui se termine en biseau-presque tranchant, et qui doit frapper sur la batterie: la mèche doit être de deux à trois lignes (5 à 7 millimètres de largeur; plus large, elle serait trop fragile ; plus courte, elle donnerait moins d'étincelles;.

2.° Les flancs ou bords latéraux, qui sont toujours un peu irréguliers ;

3.° Le talon, qui est la partie opposée à la mèche, et qui a toute l'épaisseur de la pierre;

4.° Le dessous de la pierre, qui est uni et un peu convexe;

5 .° L'assis, qui est la petite face supérieure placée entre l'arête qui termine la mèche, et le talon; elle est légèrement concave: c'est sur elle qu'appuient les mâchoires du chien de la batterie, pour la maintenir dans sa place.“

REF 40: Aide - Mémoire al'usage des Officiers d'Artillerie de France. Cinquième Édition, II. Paris 1819, 1285 p.

Pg. 605:
„Les instruments pour les tailler sont:[56]
1 petite masse de fer à tête carrée, sans acier ;
1 marteau à deux pointes, de bon acier ;
1 petite roulette d'acier non trempé, qui est un troisième marteau.
1 Ciseau en biseau des 2 côtés... et 1 lime pour l'aiguiser. Ce ciseau est sur billot plat ; il est incliné de 20° environ, vers l'ouvrier qui s'assied en avant.
La pierre à Fusil a 5 parties :
La mèche, qui se termine en biseau presque tranchant, qui doit frapper sur la batterie, doit être de 2 à 3 lignes de largeur ; plus large, elle serait fragile ; plus courte, elle donnerait moins d'étincelles. Cependant, dans l'Artillerie, on exige que la mèche ait 6 lignes, et on s'en trouve bien.
Les flancs, ou bords latéraux, toujours un peu irréguliers.
Le talon, qui est opposé à la mèche, et a toute l'épaisseur de la pierre.
Le dessous, qui est uni et un peu convexe.
L'assis (légèrement concave), qui est la face supérieure, entre la mèche et la talon.
Il faut une minute au plus pour faire une pierre.
Un bon ouvrier prépare 1000 écailles en un jour ;
Ou, fait 500 pierres (350 de guerre et 600 de commerce par lui et sa famille.)
En 3 jous, il fend et finit 1000 pierres.
Les déblais montent au ¼ des blocs.
Il n'y a que le moitié des écailles qui sont bonne.
Le moitié des masses ne peut être écaillée.
Le plus gros bloc ne fournit que 50 pierres.
Des écailles trop grosses, on fait les pierres à briquet.“

3.2. England

REF 41 (=REF 29): Skertchly (1879).

Pg. 16-20:
"The gun-flint makers' tools require more detailed description, and will be described in the order in which they are used, viz., those used (1) in quartering, (2) in flaking, (3) in knapping.

Quartering Hammers *are of two sizes, the larger being called the First and the smaller the Second quartering hammer. () The weights vary, but those in the collection are average specimens, and weigh 6 lb. 14 oz., and 3 lb. 4 oz. respectively. The hammers are hexagonal in section, and taper but slightly so as to leave the face large. They are made of iron, steel-faced, and when the face wears they are re-steeled. The old, first quartering hammer in the collection shows one used-up face. It has been in use for 20 years. The old, second quartering*

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[56] Compare REF 39, Dolomieu (1796), 706-707.

hammer is in excellent working order, and is about 15 years old. The workmen prefer them in this state to new tools, because the face is worn to the proper shape.

Flaking Hammers *are also of two sizes, known as the First and Second flaking hammers. Those in the collection weigh respectively 1 lb. 12 oz. and 1 lb. 4 oz. They are made of steel, have a square section, and taper so as to terminate in a small square face, as shown in Fig. 5. On the centres of the sides the hammers are flattened for the purposes of striking off irregular projections on the quarters. As the blows are given with only a portion of the face that portion wears down until it becomes useless; the other face of the hammer is then used, and when this is worn the handle is taken out and fitted the other way into the eye or socket so as to bring the unused portions of the faces into play. When these become worn the faces are filed up square. ()*

With a flaking hammer of given sized face and weight there are a maximum and minimum thickness which cannot be exceeded by any flake struck thereby; there is likewise a minimum force to be applied to dislodge a flake, a blow of less weight failing to do moire than bruise the stone: and a maximum, which if exceeded shatters without flaking the flint. With heavy hammers longer flakes can be struck than with light ones.

English Hammer. - *Prior to the Introduction of the French hammer the Brandon people used an oval hammer (). English hammers are never made specially.*

Knapping Hammers *are made from 9-inch flat-files drawn out as shown in Fig. 7. They require delicately tempering, or they will fly instantly. Mr. Wyatt states that the heads are set on obliquely. If he refers to the setting of the heads on the handles he has fallen into an error, but if to the set of the hammer on the flint he is correct. The edges at first are quite square, but they soon wear and require filing up daily. They generally become hollowed out in the centre, as is the case with the old one in the collection; much, however, depends upon the individual peculiarity of the knapper, each of whom can tell his own by the manner in which it wears. If the edge is not kept square it is apt to gap or split the flints. ()*

A quick knapper wears out a hammer in a fortnight. ()

The Blocks *are made of the boles of large elm trees, and measure about 4 feet in diameter and 2 feet in height. () The blocks are placed by preference against the wall (), and slope gently forwards. At a distance of about 4 inches from the side the stake is placed.*

The stake *is a piece of iron about 6 inches in length and 1 inch square at the shoulder, tapering to a point below. () The height of the stake varies with the kind of gun-flints to be made upon it, this height being called the fall. For ordinary flints the fall is about 1 ¾ inch; for muskets, 2 inches; but some knappers like a greater fall than others."*

Pg. 27-32:
"In the process of manufacture there are four processes - drying, quartering, flaking, and knapping.

Drying. - *The stone is brought from the pits and shot down outside the shops where in the summer it dries very rapidly, but in the winter remains wet. In the summer the stone is brought inside the shops and often worked at once, but it is now becoming the practice to sprinkle water over the blocks; the reason assigned being that it "lays the dust." The quarry-water, however, is always got rid of, and hence in winter the stone is stacked round the fire-place to dry. Water is not sprinkled on the stone in winter, the flint being so hygroscopic that it is always damp outside. Even the dry flakes will turn damp when the atmosphere is moist, and then they are sometimes dried over again.*

Quartering. - *A block of stone is then taken and quartered. The workman sits on a stool placed in front of a window or door, and is very careful about setting it slightly sloping forward so as to incline the body, and obviate the necessity for bending, which would lead to back-ache. Some workmen are very particular about their stools, and will spend half-an-hour*

in the adjustment; and in summer, when the stool is placed opposite the door, will rather jump over it than shift it.

The workman wears a large leather apron, and on his left knee a knee-piece made of pieces of old boot-tops about 6 inches by 12, on the top of which is a cross-piece, made by preference from a stout boot-sole, or failing that from a piece of old harness. The cross-piece is about 6 inches by -3 inches, with a hole at each end by which the entire knee-piece is bound lightly across the knee with a leather thong called a knee-piece string. The blocks of stone are taken just as they are delivered, and vary in weight from about a quarter of a hundredweight to nearly two hundredweights. One is placed against the knee so as to bring a flat or hollow part upon the knee-piece for the hammer to strike upon. It is then slightly tapped with the quartering hammer, the large or small one being used according to the size of the stone. The tap tells the Workmen whether the stone is sound or not. If it is full of cracks it flies to pieces with a jarring sound. If the coat is hard and the hammer rings, the stone is sound. If the hammer falls dull and jumps, the stone is sure to be double-coated, and grey or mixed colour beneath the coat. Sometimes pieces fall out on tapping the stone which have a sub-conical inner surface; these are known as pot-lids.

The stone is then quartered or broken into pieces of a convenient size to work. The blow is given from the elbow, the hammer being raised about a foot and allowed to fall, little or no power being put into the blow. Tiie stone is nearly always struck from the natural upper surface, because the bottom coat is softer, and the hammer does not bite. If, however, as occasionally happens, the bottom coat is the harder, it is quartered from below. The stone has to be broken so as to leave a more or less square edge to begin flaking from. The quartered pieces average about six inches square, but there is no regularity in the size.

Flaking. - *The next process is flaking, which is performed on the same stool as was the previous process, the workman quartering a stone and then flaking it up. This is the most difficult branch of the business, and requires great skill and nicety of judgment. The stone must be struck at the proper angle, in the exact spot, with a certain force, and by a given portion of the face: and all but the first of these elements vary with every flake. Many knappers are unable to flake, and but few attain great proficiency in the art. The quarter is grasped in the hand and the face brought against the knee-piece at an angle of about 45°. The blow is then given by raising the flaking hammer (large or small according to the size of the stone) from the elbow about 2 inches, and allowing it to fall by its own weight, or with a slight extra force according to the size of the quarter. The stone is struck squarely, but not with the whole f ice of the hammer. If the flake is to be thin, the blow falls just inside the face; if thicker, a little further in, but a flake could not be struck to any purpose if the whole face fell on the stone, and this is the limit of thickness for flakes produced by any hammer. The outside flakes, called "shives", which show the coat, are thrown aside as waste, and by removing these the block is made to assume a rough, many-sided, polygonal form. The next series of flakes are so struck as to fall a little to one side of the previous blows, and the flake runs so as to include the angles or ribs of two of the first flakes, and it is thus double backed. The edge of this flake leaves another rib. The next flake is struck a little to one side of the similar one in the previous series, nud so on. In this way the flaker works round the quarter and removes from two to three rows of flakes, according to the quality of the stone. ()*

When the quarter is worked up an edge is left ; the stone is then turned over, and a flake struck off with the English hammer. Such flakes are called English flakes and have no ribs, and are used for making common flints. ()

Knapping. - *The final process is knapping, or the forming of flakes into gun-flints. The knapper sits on a stool at the block, and is equally particular with the flaker as to its position. The block slopes gently towards the flaker, and the stake slightly inclines in the same direction. Until recently the stake was set upright, but it is now becoming the practice to incline it. The flaker sits close to the block and at right angles to it. The left leg is extended*

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parallel and close to the block, and the right leg is bent. The workman wears a large cotton apron over both knees, and hitches one end of it on to a tack behind him; this apron catches any pieces which fly. The flake is taken in the left hand, and the knapper tells at a glance and by the touch how many and what sorts of gun-flints the flake will make. A good flake will make four, and a very good one five flints. ()

The part of the hammer nearest the body is called the hind corner, the opposite end the fore corner. The flake is struck squarely on the face just inside the stake, so that a shearing force is applied, and the hammer lies with the hind corner and about half the edge on the Hake. If the flake is thick the fore corner of the hammer is used, but not otherwise. ()

The workman first determines which side of the flake is to form the edge, choosing the straightest and best for that purpose, and holding the flake so that the edge is away from him, the face of the flake being uppermost. The edge and heel are made from the sides of the flake, the sides by the cut section of the flake. The first operation is to cut the flake across to form the right side of the flint (the flint being looked at with the heel nearest the body) and chisel it straight with one or two slight blows. The flint is then turned towards the knapper and the heel cut and chiselled, this being done so rapidly that it is almost finished during the act of turning. The flake is again turned towards the body and the other side cut. Turning again in the same direction and at the same time turning the flint back uppermost the edge is trimmed. These motions are so quick that the flint never seems to stop in being turned, yet every blow has to be considered and delivered according to the individual necessity of the case. The edge is often put on by scraping the face along the back of the stake, and though in many instances this trimming is unnecessary the knapper almost always does it from custom.”

3.3. Italy („Welsch Tirol“)

REF 42 (=REF 7): Bergbaukunde (1790).

Pg. 387-388:

„Die auf den obbeschriebenen Gebirgen legenden Findlinge, oder aus den bisher aufgeschürften Oberflötzen genommene Ganze, oder Stücke der grössern Geschiebe, werden angeschlagen, um zu sehen, ob der Stein die gehörige Festigkeit, und genug grosse Blätter zu einer der Feuersteingattungen habe, und wie die Blätter liegen. Diese werden alsdann zu Ersparung der überflüssigen Gewichtsübertragung, gleich bey dem Gewinnungsorte mit der, etwas zugespitzten Seite einer Art von Stufeisen, eines nach dem andern abgepeikt. Da ein Kiesel sehr irregulair bricht, so gibt es kleine und grössere, doch mehr kleinere, und sehr viele zu kleine, und ganz unbrauchbare Blätter oder sogenannte Feuersteinschalen. Die zu den 3 Artillerie Feuersteingattungen, oder sonst wenigstens zu Jagd- Küche- und Tobackfeuersteinen tauglichen Schalen, werden für die Arbeiter gesammelt, und in den weitern Bearbeitungsort getragen, woraus alsdann auf kleinen, ¾ Zoll dicken, in hölzernen, in die Erde geschlagenen Pfählen steckenden eisernen Stiften, mit einer 8 oder 9 Zoll langen, 2 Zoll breiten, und ½ Zoll dicken Eisenschiene, die der Grösse und Dicke der Schale angemessen, entweder hinten abgerundeten Musketen- Carabiner- und Pistolen-, oder nur kleine zweyschneidige Jagd- und Küchenfeuersteingattungen vollends fertig gemacht werden. Eine solche Schale gibt nur einen Stein ab, obwohl solche meistens zwischen 2 bis 4 Zoll lang, ½ bis 2 Zoll breit, und ¼ Zoll dick sind.

Es fällt also viel weg, und dürfte etwas wirtschaftlicher umgegangen, und aus vielen Schalen zwey, entweder ein grösserer, und ein kleinerer, oder 2 kleine Flintensteine gemacht werden können.“

REF 43 (=REF 20): Hacquet (1792).

Footnote pg. 53:
„In den 2ten Theil der Bergbaukunde Leipzig 1790 wird auf der 387. Seit gesagt, dass aus einem Schiefer nur ein Stein gemacht wird, die Steinart muss also zu brüchig seyn, oder man verstehe die Manipulation nicht recht, es ist aber zu vermuthen dass damals als dies geschrieben wurde von beiden Seiten der Fehler war, denn was die Beschreibung belangt wie Flintensteine geschlagen werden, ist so Dunkel gesagt, dass kein Mensch klug daraus werden kann, vielleicht hätt es ein Geheimnis seyn sollen."

REF 44 (=REF 4): Ployer (1800).

Pg. 156-160:
„Auch werden sogleich auf der Eroberungsstätte die Blätter, welche die Fabricanten Scaglie nennen, weil sie fast wie dicke lange Schuppen abfallen, ausgeschlagen, damit das Unnüze auf der Stelle bleibe, und nicht vergebens nach Haus getragen werden müsse. Das Werkzeug hiezu besteht bloss in dem Hammer (), der vorne einen wirklichen Hammerkopf hat, rükwärts aber in eine Spize zusammenläuft.
Esterer dient, die Kugeln und Klumpen anzuschlagen, ihre Güte zu prüfen, sie von der Schaale zu reinigen, und das Unganze abzufördern; letztere hingegen bloss allein, um die Blätter, oder Schuppen auszuschlagen.
Dieser Hammer darf keinen Stahl haben; denn unter demselben würden die Steine bersten; besonders soll die Spize von dem weichsten Eisen gemacht seyn; daher sie bei dem Streiche an den Stein sich gleichsam anzukleben scheint.
Diese Aufschlagung der Blätter erfordert viele Uebung, und ist eigentlich in der ganzen Manipulation der heiklichste Handgriff; wenigstens gehört dazu eine durchaus gleichtreffende Gewissheit des Schlags.
Das zum Ausschlagen vorgerichtete Steinstük wird so in die linke Hand gelegt, dass die Schuppen, in die es sich spalten lässt, quer über die Hand, doch mit der Fläche derselben parallel liegen; dann wird mit der Spitze des Hammers 2 bis 3 Linien hoh über der Boden – Lage desselben in der Mitte gegen den Leib gewendeten Seite mit einer mässigen Gewalt an den Stein geschlagen, wodurch ein Blatt, oder eine Schuppe nach der Länge des Stein abfällt; hiemit wird fortgefahren, so lange der Stein noch brauchbare geben kann.
Diese werden in einem Schulterkorbe zu Haus getragen, und dann fängt die Zuformung in Büchsensteine an.
Hiezu sind keine andern Werkzeuge, als ein Auflagstift (), und die Abschlag – Schiene (), beide von weichem Eisen nöthig.
Etstere wird in einen Holzstok gesezt (), die Schuppen mit der linken Hand darüber gehalten, mit der rechten hingegen die Schiene bei b gefasst, und mit der Fläche a (nicht aber mit der Kante) die Blätter zuformt, welches eine sehr leichte Arbeit ist, so, dass ein fleissiger Fabricant in einem Sommertage 1200 bis 1500 Stücke fertigen kann.
Diese Arbeit richtet sich nach der mehrern, oder mindern Grösse der Blätter oder Schuppen. Die breitesten und stärksten werden zu Musketensteinen, die mittelmässigsten zu Carabinersteinen, und die kleinern zu Pistolensteinen, alle drei Gattungen mit runden Stücken gebildet, wo dagegen die dünnsten Blätter zu zweischneidigen Jäger- und Terzerolsteinen verarbeitet werden."

Pg. 160 (Anmerkung):
"Man vergleiche hiermit Hacquet's physische und technische Beschreibung der Flintensteine, Wien, 1792, 80. Eine weitere Ausführung seiner Beschreibung samt Abbildung der

Werkzeuge, womit die Flintensteine zu Muene im Gouvernement Berry in Frankreich und anderwärts verarbeitet werden, im Höpfner'schen Magazin für die Naturkunde Helvetiens, IV. B. S. 525-542. Die Manipulation zu Avio scheint noch einfacher zu seyn."

REF 45: Benetti, A. (1977). Manufatti di selce preistorici e storici a Camposilvano nei Lessini Veronesi. Studi trentini di scienze naturali. Acta biologica 54, 197-209.

Pg. 204:
"I folendari erano divisi in due categorie: i cataori (trovatori) e i bataori (battitori)...erano specializzati nel preparare pietre da acciarino per i fucili o per il fuoco...Quando l'officina era zeppa di scarti silicei il bataor prendeva alcuni di questi cumuli e li gettava nelle diaclasi dei vicini affioramenti calcarei del Rosso ammonitico...
I cataori erano dotati una Krakesa sulla quale legavano una cassetta che serviva a contenere le selci, ed una zappa per levare la cotica erbosa dai detriti di falda o dei depositi alluvionali. La loro specializzazione consisteva nel raccogliere gli arnioni ed i noduli di selce, badando che avessero la corteccia sottile e scartavano le specie di selce vetrose, da essi chiamate folende mate, che per troppa fragilità non erano adatte..."

3.4. Galicia

REF 46 (=REF 20): Hacquet (1792).

Compare **REF 38: Hacquet (1789).** The following text is an extended version of the publication from 1789, and in great parts identical.

Pg. 48-56:
„Zum Flintensteinschlagen gehören folgende Werkzeuge:

Erstens ein stumpfer oder Bruchhammer Marteau cassant () und hat gegen 2 Pfunde an Schwere.

Zweitens ein Spitz- oder Schiefer- Hammer Marteau à pointe ou marteau fendent (). Der stumpfe 2 der scharfe Spitz, wenn die Stumpfe das hier angezeigte Maass übersteigt, so greift das Instrument nicht mehr an. Dieser Hammer hat die Schwere des vorigen.

Drittens der Scheibenhammer la roulette (), mit dem Stil, dieser wiegt von 6 bis 8 Loth, nachdem man grössere oder kleinere Steine zum Zurunden hat, erfordert die Stahlscheibe auch mehr oder weniger Schwere oder Gewicht.

Viertens das Meissel, Ciseau, welches an beiden Enden Schärfe hat, dieses hat an Gewicht ein halb Pfund, und manchmal darüber ().

Fünftens eine gemeine Stahlfeile um den abgenutzten Meisel die Schärfe wieder zu geben.

Sechstens, eine Bank, worauf ein kleiner Klotz befestiget ist. Table a Boucaniere, und worinn das Meisel fest gemacht um darauf die mit dem zweyten Hamer gemachten Schiefers zu Flintensteinen zuzurichten. Um das Meisel nach Belieben heraus zu nehmen, oder umzukehren, ist solches mit einem paar kleiner hölzernen Keile befestiget. Eine solche Bank und Tisch muss auf 3 Füssen gesetzt seyn, und die gehörige Höhe für den Arbeiter haben. Das

ganze muss von harten Holz seyn. Es ist besser, dass ein jeder Arbeiter seinen eigenen Werkstuhl habe, als dass zween oder mehrere um einen Klotz sitzen, um von den abfahrenden kleinen Splittern nicht beschädiget zu werden. ()

Wenn man nun zur Arbeit schreiten will, so müssen, wie oben gesagt worden, die Klötze, Knauers, Steinkugeln u.s.w. die von 1 Pfund bis 3 Zentner schwer gefunden werden, die gehörige Trockne haben; ()

Ist der vorhandene Stein des Zurichtens fähig, so wird, wenn er nicht zu gross ist (die grossen von 1 Zentner, und darüber werden, von ein paar Arbeitern in die Höhe gehalten, und von einem Dritten mit einem Hammer gespalten, indessen kann dieses ebenfalls auch auf weichen Boden geschehen) sitzend, so wie die ganze Arbeit verrichtet wird, mit der linken Hand über das linke Schenkelbein dem Knie nach einwärts festgehalten, dann wird mit dem stumpfen oder Bruchhamer ein Anbruch, oder ein paar Zoll grosses Stück von dem Ganzen abgeschlagen. Dieser Anbruch muss jederzeit da geschehen, wo der Wirbel oder Knorbel, das ist, wo der Stein zusammen gedruckt, oder gespiszt zugeht, wie schon oben erwehnet worden, geschehen. ()

Nach diesem wird Zweitens der Bruchhammer weggelegt, und wird dafür der Spalt oder Spitzhammer in die Hand genommen, wenn nicht die eine Hälfte des Hammers zum Brechen, und die andere zum Spalten zugerichtet ist, um damit den Stein in länglichten Schieferstücken zu versetzen. ()

Die Fassung des Steines mit der linken Hand beim Spalten muss solchergestalten schief gehalten werden, dass das obere Ende, wo man mit dem Schieferhammer einhauet, etwas vorhenke; () Die zwei oder drei ersten Schiefer, die man von dem Stein abschlägt, sind zu Flintensteinen selten, oder gar nicht tauglich, indem sie gewölbt, oder auch wohl mit einer Rinde überzogen sind, und haben nicht die gehörige Richtung der Rippe, die um einen ordentlichen Flintenstein zu bilden nothwendig ist. Wenn man einmal mit dem Schieferschlagen angefangen hat, so muss beobachtet werden, dass der Spitz des Hammers, welcher etwas breitschneidig oder auch zugespitzt seyn kann, nur so weit von dem Rand des Steines eingesetzt wird, als man Willens ist, grössere oder kleinere Steine zu machen, das ist von zwei bis fünf Linien breit, giebt die gehörige Dicke für alle Steine ab. () Bei dem Schieferschlagen oder Abhauen muss man jederzeit Rücksicht nehmen, wo man mit dem Hammer einhauen soll, damit die Schiefer so ausfalle, dass er in der Mitte eine Rippe erhalte…()

Die () Flintensteine, welche aus einem solchen Schiefer gemacht werden können, fallen 2 bis 8 von einem solchen Schiefer ab.[57] Da man aber in der Arbeit so genau nicht Acht hat, ob man zwei, drei oder mehr Linien tief in den Stein einhackt, so pflegt man meistens ohne Rücksicht der Dicke Schiefer zu schlagen, welche beim Zurichten nach verhältnissmässiger Dicke bald zu Pistolen oder Flintensteinen gebildet werden.

Drittens die Zurichtung der Steine aus den geschlagenen Schiefern geschicht folgends.

Der Arbeiter setzt sich auf den oben erwehnten Stuhl, Bank, oder Zurichttisch; ()
Nun nimmt er in die linke Hand () einen von den erwehnten Schiefern, und hält ein Ende davon so breit über die Schneide des Meisels, als er einen breitern oder schmälern Stein zu machen im Sinn hat; () Nun giebt er mit seinem Scheibenhammer, der mit einem runden Stiele versehen ist, zwei drei oder mehr gelinge Schläge auf dem Schiefer den er wie gesagt mit der linken Hand hält, und auf der Schneide des Meisels gehalten, um dass er von unten auf angeschnitten wird; so dass dies geschehen, hält der Arbeiter den Schiefer von dem Stemeisen in die Höhe, und schlägt mit dem Hammer daran, wo dann das angeritzte Stück abspringt,

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[57] The footnote refers to REF 7, Bergbaukunde (1790), pg. 387.

und so fahrt er so lange fort mit diesem Anritzen und Abschlagen bis er seine Schiefer in beinahe viereckige Stücke zersetzet hat ().

Viertens nun wird die letzte Hand angelegt, den Stein vollkommen zu bilden. Diese gemachten irregulären Vierecke werden nun wieder eine um die andere in die Hand genommen, um den Haft zu bilden, das heisst der schlechteste oder kürzeste scharfe Rand wird zugerundet, um dem Kopf oder Haft, wenn nicht aus dem Schieferstücke ein Doppelstein entstehen soll, gemacht."

REF 47: (=REF 33): Hacquet (1806).

Pg. 114-116

„Bei der Bearbeitung der Flintensteine habe ich zu erwähnen vergessen, daß bei einer solchen Fabrik die Arbeiter in zwei Parteien getheilt sind, wovon die eine bei weitem kleinere bloß mit dem Spalten der Steine, oder dem sogenannten Schieferschlagen sich abgiebt, welches mehr Geschicklichkeit und Einsicht fordert, als das Geschäft der zweiten, die sie vollkommen zuzurichten hat. ()

Ein guter Spalter muß wenigstens drei oder vier Zurichter beschäftigen, ja mancher bringt es da hin, daß er in einem Tage so viel Splitter haut, als fünf Zurichter kaum aufzuarbeiten vermögen. Die Zurichter sind meistens Knaben von 12 bis 6 Jahren. Ein fleißiger fertigt tausend bis fünfzehn hundert Flinten= und Pistolensteine in einem Tage; je mehr er macht, oder gehörig zurichtet, desto größer fällt sein Lohn aus, wenn zu Ende der Woche seine Stücke abgezählt werden. Der Spalter, so wie der Zurichter, ist gehalten, seine Schiefer oder Steine zu sortiren; zu diesem Ende hat ein jeder sein Kästchen mit der Abtheilung bei der Arbeit."

4. Economical aspects

REF 48 (=REF 16): Letter from King Friedrich II from Prussia to general von Linger, 30ᵗʰ July 1751 (text adopted from Seel (1981), 1453-1454).[58]

„Mein lieber General von der artillerie von Linger und Major Diskau!
Es ist mir recht lieb gewesen, aus Eurem Schreiben vom 22. dieses zu ersehen, daß ihr Euch mit dem Kaufmann Splittgerber Concertiert habet, damit dieser jemanden expreßt nach Frankreich abschicke, um ohne eclat Leuthe zu engagieren, welche mit dem Spalten derer Feuersteine um solche zu flintensteinen zu adjustieren um zugehen wiße, und dienet Euch demnächst, auf Eure gethane Anfragen, zu resolutieren, daß Wir nur zwey dergleichen Leute hier nöthig haben werden."

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[58] According to REF 37, Jakobsons technologisches Wörterbuch (1781), Friedrich II.'s father already undertook a similar undertaking 30 yeas earlier. The only difference is the applied strategy: Under Friedrich Wilhelm I., David Splitgerber (1683-1764, one of the most prominent merchants in Prussia at that time) sent Matthias Klose to France in order to learn the art of gunflint knapping. Friedrich II commissioned Splitgerber again, this time with the objection to lure flintkanppers away from the workshops.

REF 49 (=REF 37): Jakobsson (1781).

See above, concerning industrial espionage on behalf of the King of Prussia, Friedrich Wilhelm I., in 1722.

REF 50 (=REF 38): Hacquet (1789).

Pg. 527-528: The "Klose - story", footnote pg. 527: S.K.G. Jacobsson, Technologisches Wörterbuch 410[59] Berlin 1781 **(REF 37).**

„Es wurde ein gewisser Matthias Klose nach St. Anges, ein kleines Städtchen in dem Gouvernement Berry, wo ansehnliche Flintenstein=Bergwerke sind, geschickt; bey Lebensstraf darf aber kein Fremder diese Bergwerke sehen. Er brachte einen 6. Pfund schweren Flintenstein mit aus St. Anges, wo er ein Vierteljahr zubrachte, um die Bearbeitung zu erlernen, aus diesem machte er im Lande Flintensteine, welche auch die Probe aushielten. Nachher mußte er gleichfalls Flintensteine aus einheimischen Feuersteinen verfertigen, und diese fand man in Spessenberg bey Neustadt, Eberswald in Mittelmark. Er verfertigte die Steine mit Glück, und es wurden hiemit Proben angestellt, sie zersprangen aber nach dem zweyten Schuß, und die ganze Sach gerieth darüber ins Stecken. Die Handgriffe beym Bearbeiten der Feuersteine, sind kürzlich diese: Vermittelst eines stählernen Werkzeugs wird der Stein erst mit der Faust stückweise abgeschlagen und gespalten, denn er ist schieferich und splitterich. Mit einem andren stählernen Werkzeuge schlägt man ihn zu seiner gewöhnlichen gestalt, und er gehet überdem noch zey bis dreymal durch die Hände, je nachdem er sich leicht oder schwer bearbeiten lässt. Die Werkzeuge deren sich Klose damals bey seiner Probe bediente, sollen noch in Berlin bey der Artillerie aufbehalten werden.“

Footnote Pg. 528:
„Goeze hat in seynem Allerley I. Thl. S. 56. auch eine Beschreibung, mitgetheilt, wie diese Flintensteine in Champagne verfertigt werden. Diese lautet ganz anders und etwas unbegreiflich. Er sagt: der Flintenstein sey unter der Erde so weich als Speckstein, und werde mit Drath (gleichwie man Seife zerschenidet) in seine Formen zertheilt.“

REF 51: Goeze, J.A.E. (1788). Nützliches Allerley aus der Natur und dem gemeinen Leben für allerley Leser. Erster band, Neue verbesserte Auflage. Leipzig, 472 p.

Pg. 37:
„...Dies (= lacking knowledge of the art of gunflint production, ed. Note) *bewog mich vor einigen Jahren, einem erfahrenen Manne im Steinreiche, der nach Frankreich reiste, die Commission zu geben, sich doch nach dieser Sache aufs genaueste zu erkundigen. Als er zurückkam, sagte er: Es sey ein großes Geheimnis, und er habe fast ohne Lebensgefahr nicht dahinter kommen können.*
In Champagne und in der Piccardie sey die Materie, woraus die Flintensteine gemacht würden, als eine weiche Masse in der Erde, fast wie der Speckstein.
Aus dieser Masse würden die Flintensteine, unten in der Erde, von gewissen Leuten, mit Drath abgeschnitten, in der Form, die sie haben sollen. Dann würden sie zu Tage gebracht, da sie an der Luft trockneten.“[60]

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[59] The page number is not identical to REF 37.

REF 52: Hacquet, B. (1789). Einige Nachrichten über ein mächtiges Lager von Flintensteinen in Pokutien, und deren Zurichtung; vom Hrn. Prof. Hacquet, in: Crell, L. (ed.), Chemische Annalen I. Helmstadt und Leipzig, 102-105.

Pg. 103:
„Zu diesem Ende ließ der König einen Büchsenschäfter (Matthias Klose, ed. Note) *nach Frankreich reisen, die Zurichtung dieser Steine zu erlernen; allein, da der Mann ein Ausländer war, so mag man bald abgenommen haben, daß er nur in der Absicht dahin gekommen sey, um den Vortheil der Zurichtung zu erlernen; daher man ihm also den Besuch der Steinbrüche, oder besser der Gruben versagte, aber doch gewiß nicht bey Lebensstrafe, wie erwähnt wird, indem einem jeden frey steht, in dem Berryschen, die Bearbeitung der Flintensteine zu sehen, wenn man es sich nicht merken lässt, diesen Leuten dadurch die Nahrung entziehen zu wollen."*

REF 53: Hohenhausen und Hochaus, S.J. von (1796). Ankündigung eines neu entdeckten Landes=Produkts in Baiern, und in der Obern=Pfalz. Dieses Produkt ist Der nur in so wenig Ländern von der Natur herfürgebrachte Wahrhafte Flintenstein. München, 52 p. Source: Bayerische Staatsbibliothek.

Pg. 6:
Seit der Erfindung des Feuergewehrs; haben alle Länder von Europa, ja alle vier Welttheile, ihr Geld nach Frankreich um Feuer= und besonders um Flinten=steine geschickt.

Pg. 7:
*„Das Technologische Wörterbuch des Jakobsons aus Berlin[61], zeiget an, dass Friedrich Wilhelm König von Preussen, einen gewissen Bergrath Mathias Klose, mit vielem Gelde in die Provinz Berry nach Frankreich schikte, um das Gestein sowohl, als auch dessen Bearbeitung kennen zu lernen.
Ein Fremder darf, bei Lebensstrafe die Flintenstein=Werker nicht sehen."*

Pg. 10:
„Nun hat aber Hacquet selbst erst, im letzten Jahr des Türkenkrieges, in Podolien jenen Stein entdekt, aus denen doch Flintenstein für die k. k. Armee erzeugt werden können; bis zum Kommerzeinzweige aber, sind sie noch nicht recht gediehen. Es ist immer noch nicht der wahre Flintenstein, denn er ist rau, hart, spröde, ungeheuer groß, und lässt sich nicht ins Feine bearbeiten, zum wenigsten zeigen dieses einige hundert tausend, die wir uns, endlich aus Noth, davon haben verschaffen müssen."

Pg. 11-12:
*„In dieser allgemeinen Noth um diesen Artikel; erschienen nun die italienischen Spekulanten mit ihrer bisher ganz ungeachteten, und gleichsam verworfenen Waare.
Sie sind dünne, milchartig, weich, schlecht bearbeitet, und springen wie Glas, als erzeugt, aus einem nicht ächt flintensteinartigen Gesteine.*

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[60] Compare REF 58, Förtsch (1892), 372; the rumor, that gunflints were cut in a soft condition with a wire rope, appears in several literary sources, and may reflect intentional disinformation, probably spread by the French in order to preserve the industrial secret.
[61] REF 37, Jakobsons technologisches Wörterbuch (1781).

Da diese Art ziemlich ergiebig, auf der tirolisch=venetianischen Gränze gefunden wird, und von den Taglöhnern, ohne viele Mühe, meistens schlecht, und unförmlich bearbeitet, also auch von ihnen fast zum Spottgeld an die Kaufleute in den Städten verkauft wird, so haben sie sich auch in den benachbarten Ländern ziemlich eingeschlichen.
Die kleinen Krämer, haschen fürnämlich mit Begierde darnach; indeme sie selbe dem nichts untersuchenden gemeinen Manne, um so eher anhängen; als sie ihm selbe wohlfeiler geben, als die wahren und guten, unbekümmert darüber, ob ein etwas theurerer wahrer Stein besser dienet, als zehn solche falsche Steine.
Die kaiserliche Armee selbst, und überhaupt keine Armee aber, kann sie auf den Gewehren brauchen."

REF 54 (=REF 28) : Gillet-Laumont (1798).

P 718 :
„Il raconte qu'à l'époque où l'Empereur Joseph II vint en France (en 1776), il envoya à Meunes des gens qui ne parvinrent que très difficilement à déterminer un jeune homme à les accompagner Autriche; mais que ce jeune homme revint à Meunes quelques mois après, annonçant qu'il n'avait pas trouvé de cailloux propres à la taille.

Footnote 1: ( ) Ce fait n'est pas exact à présent, quoiqu'il ait pu l'être anciennement. On commence, dans beaucoup de pays, à faire usage des, silex qui s'y rencontrent, pour les tailler en pierres à fusil. On lit dans l'ouvrage intitulé l'Art des mines (en allémand Bergbaukunde)[62], 2.e volume, art. XI, qu'on exploite et qu'on taille, pour le service militaire de l'Autriche, des silex qui se trouvent en couches alternant avec des couches de craie, des deux côtés de l'Adige, dans le Tirol italien, près d'Avio. Les collines secondaires qui les renferment se nomment le «felve del monte Baldo»: elles règnent au pied de la montagne de ce nom, dans la vallée d' Acque nere. On trouve dans le méme canton beaucoup de ces silex épars à la surface du terrain."

REF 55: Buse, G.H. (1801, ed.). Das Ganze der Handlung oder vollständiges Handbuch der vorzüglichsten Handlungskenntnisse I – 5. Erfurt, 604 p.

Pg. 549:
*„Neben diesen Flintensteinen (*from Welsch=Thyrol, ed. Note*) bedient man sich noch heutiges Tages in Thyrol der harten eisenhaltigen Granate; ()"*

REF 56: Anon. (1803). Kunstfleiß in Fabriken und Manufakturen. Kunstgeschichte der Flintensteine, in: Hildt, J.A. (ed.), Magazin der Handels- und Gewerbskunde. Erster Jahrgang, Januar 1803, Bd. 1., Teil II. Weimar, 118-128.

Seite 128, Abs. 3:
„Die größten Vorräthe von den Flintensteinen hat man immer in Holland angetroffen, um sie theuer zu verkaufen, wenn Frankreich zur Zeit des Kriegs die Ausfuhr verbieten sollte; außerdem auch für ihre Ost- und Westindischen Niederlassungen. Auch die Städte am Rhein haben stets große Niederlagen davon unterhalten, und besonders werden von Frankfurt am Mayn starke Versendungen davon gemacht."

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[62] REF 7, Bergbaukunde (1790).

REF 57: Anon. = Hoyer?[63] (1831). Ueber Feuersteine und Flintensteine, in: Decker, B. von & L. Blesson (eds.), Zeitschrift für Kunst, Wissenschaft und Geschichte des Krieges 23/9.Berlin, Posen und Bromberg, 201-212.

Pg. 204-205:
„Im Jahre 1811 besah ich die Umgegend von Krzezowiz bei Krakau und traf zufällig auf die dortigen Flintenstein=Schlägereien, anders weiß ich die Anstalt nicht zu nennen, da man durchaus von dem Ausdrucke Schneiden abstrahieren muß, um keine falschen Begriffe zu erregen. – Hier wie überall wurde ein großes Geheimniß aus der Arbeit gemacht; ich konnte nur Instrumente verstohlen erblicken, die ganz mit denen in Hermbstadt's Museum beschriebenen übereinstimmten, und bemerken, dass Feuer bei der Arbeit angewendet werde. – Die Lagerung des Fossils durfte ich auch nicht genau untersuchen, und hatte sogar Mühe, an Ort und Stelle fertige Steine zu sehen, die mir dem Aeußeren und, nach diesem, dem Gebrauche nach den Französischen besten nicht nachzustehen schienen. – Jedoch legte dies in mir den ersten Grund zu ferneren Beobachtungen und Versuchen, die mich endlich ganz überzeugten, dass die Sache nur deshalb so geheim gehalten wird, weil sie zu leicht nachzumachen ist, und nur einige mechanische Fertigkeit erfordert."

REF 58 (compare REF 36): Förtsch, O. (1892). Gewinnung und Verarbeitung des Feuersteins in England, in: Luedecke, O. (ed.), Zeitschrift für Naturwissenschaften 65, 371-378.

Pg. 372:
„Leicht ist es mir nicht geworden, die Art der Arbeit moderner Flintensteinschläger zu ergründen, bis zum Druck der erwähnten Dissertation hatte ich trotz eifrigen Forschens noch keinen Menschen gefunden, der solchen Arbeitern zugesehen hatte. Dagegen begegnete ich oft den wunderbarsten Anschauungen:
Schrieb mir doch ein alter Freund, der freilich keine geologischen und mineralogischen Studien getrieben hatte, »ein Vater, der 1814 und 1815 als Soldat in Frankreich gewesen, habe mit eigenen Augen gesehen, dass dort die Flintensteine aus frisch gebrochenem Feuerstein vermittelst Drahts zurecht geschnitten würden«, also mit einem Instrument, das unserer Seifenschneide entsprechen dürfte."[64]

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[63] According to "Pierer's Universal - Lexikon" (1835, vol 7, 524), "General Hoyer discovered an outcrop of flint on the island of Rügen in 1817, and a gunflint factory was established". REF 54 is predominantly referring to attempts of the nameless author, trying to install a local gunflint manufacture on Rügen. Considering the note at the very end of the report in REF 54, which reads as follows: "*Berlin, im Oktober 1818*", there is strong indication that the author of this report was Johann Gottfried von Hoyer.
[64] Compare REF 51, Goeze (1788).

REF 59: Board of Trade, Written Answers (Commons) of 14 December 1967, Series 5, Vol. 756.

"Gun Flints (Ban on Export to South Africa)
HC Deb 14 December 1967, vol 756, c225W

Mr. Eldon Griffiths *asked the President of the Board of Trade (1) on what grounds he refused an export licence to Mr. Herbert Edwards of Brandon, Suffolk, the only master flint knapper in Great Britain, who has orders for South African flintlock muzzle loaders;*

(2) if he will rescind his ban on the sale to South Africa of flints for muzzle-loading flintlock guns.

Mr. Crosland: *Mr. Edwards was told that a license, if applied for would be refused, and the general ban is enforced, in conformity with the Government's announceced policy on the export of arms to South Africa."*

Appendix B: Gunflint workshops and raw material deposits for gunflint production in Galicia

A standardized register was found to be helpful in order to clarify the cumbersome number of workshops and raw material exploitation areas mentioned in historical sources concerning former Galicia. References are numbered internally (e.g., Nizniow 1-10) and the citations are provided at the end of each section in order to facilitate the legibility. This compendium is based on an unpublished paper by M. Penz (concerning publications from Hacquet; additional information was added by the author)[65].

1. Workshops

Gunflint workshops were usually installed in areas rich in raw material, in order to minimize transportation efforts. However, the Galician raw material deposits were in most cases not very rich in depth and therefore exploited within a relatively short time span, especially in periods of high productivity (e.g., the Napoleonic Wars). This is the reason, why some manufactories were subsequently provided with raw material from more distant sources (Penz & Trnka 2004, 240).

1.1. Brzezan

Historical name(s): Brzezan (1); Brzeczan (2) Brzeznan (3); Brzezany (4).

Contemp. Name(s): Berezhany (ukr.); Brzeżany (pol.); Bereschany (ger.).

Location: "Kreis Brzeczan", former Eastern Galicia; now Ternopil Oblast, Ukraine, situated at the river Zlota Lipa; ca. 100 km south-east of Lemberg (Lviv).

Raw material: Flint outcrops were located at the southern and western shores of a lake close to the town. No description of the visual appearance of the flint is provided in historical sources.

Workshops: The manufactory at Brzeczan was the most important facility during early gunflint production activities in Galicia, however it only existed until 1803. Hacquet (1806/1, 93; 1896/2, 6) refers to "thousands of centners of flint that were exploited, producing ca. 30 million gunflints for the Austrian army." The factory was operated by a "director Kral" and employed 50-80 knappers during periods of prosperity (1; 2). The workshops were transferred to Nizniow around 1803 (**see 1.2. Nizniow**), not because the raw material deposits were exploited, but due to the harsh climatic conditions at Brzeznan (1).

Reference(s): **1)** Hacquet 1806/1, 93; 97-98 **2)** Hacquet 1806/2, 6; 11; **3)** Appendix A, REF 21; **4)** Appendix A, REF 5.

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[65] Penz, M. (2004). Um 1800 bekannte Feuersteinlagerstätten im Kgr. Galizien *(Flint deposits known in the kingdom Galicia at around 1800)*; with kind permission.

1.2. Nizniow

Historical name(s): Nizniow (1-11).

Contemp. Name(s): Niżniów (Nyzhniv); rarer: Nichnav, Nizhev, Nizhnev, Nizhniy, Nizhnuv, Nizhnyuv, Nizniow, Niżniów, Nyzhniv (11).

Location: "Kreis Stanislawow", former Eastern Galicia; now Ivano-Frankivs'ka Oblast, Ukraine, located at the river Strepe/Strypa (a tributary valley of the Dnjestr).

Raw material: An abundance of layered black and grey flint of high quality at Nizniow and the hinterland (6); according to historical sources, the raw material was first obtained from the hinterland of Nizniow (e.g., **2.5. Zapronci-Mountains)**, and consequently brought in from Mariampol (7) or Marianopol (8), the latest since 1817 (4; see **2.2. Mariampol**).

Facts: The manufactory at Nizniow was established in 1787. After closing down the workshops at Brzeczan, N. became the principle place of Galician gunflint business. The factory was installed in a secularised monastery, where the raw material was stored and gunflints were knapped in heatable workshops during wintertime (3; 4). In 1827, an output of 2 million gunflints is mentioned (7), and 1,5 million in 1844 (9). The factory appears to be still active in the 1840s (7; 8), however in 1850 the production had ceased (10).

Reference(s): **1)** Hacquet 1790, 49; **2)** Hacquet 1792, 61;. **3)** Hacquet 1806/1, 97-98; **4)** Hacquet 1806/2, 11; **5)** Liechtenstern 1817, 1188; **6)** Appendix A, REF 5; **7)** Appendix A, REF 24; **8)** Fränzl 1841, 339; **9)** Prierer's Universal-Lexikon (1844, 33); **10)** Foetterle 1850, 85; **11)** http://de.getamap.net/ (2.11.2012).

1.3. Podgorce

Historical name(s): Podgorce (1; 2); Podgorze (2; 4); Josephstadt (ger.; 5).

Contemp. names(s): Podgórze.

Location: A suburb southeast of Krakau (ger.) in the "Bochnier Kreis" in the 18th century, today district of Kraków, Poland, south of the Vistula.[66]

Raw material: Blackish-grey and "horn-coloured" flint (= yellowish translucent, equivalent to the French *"silex blond"*), in most cases with a white cortex.

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[66] The Jewish Ghetto was situated in this district of Kraków until 1943.

| **Facts:** | Flint occured abundandly on the right riverbanks of the Vistula, between Podgórce and Wieliczka. The deposits were exploited during several years and manufactured into gunflints, first at Podgorce, and subsequently at workshops ca. 60 miles to the east. |

| **Reference(s):** | **1.)** Hacquet 1792, 40; 2) Hacquet 1806, 93 ; **3)** Hacquet 1806/2, 5; **4)** Appendix A, REF 5; **5)** Pierer's Universal-Lexikon I, 4. Auflage. Altenburg, 1857-1865, "Podgorze". |

1.4. Kerczezowitz

| **Historical name(s):** | Kerczezowitz (1; 2); Krzeszowice (3); Krzezowiz (4); ger.: Kressendorf (5). |

| **Contemp. names(s):** | Krzeszowice. |

| **Location:** | Voivodship Lesser Poland, Powiat Krakowski, ca. 25 km north-west of Kraków. REF 22 (3) refers to a sulphur spring and gunflint manufactories at *"Krzeszowice, near Krakau"*, which enables an unequivocal correlation of this production site with the contemporary town of the same name. |

| **Raw material:** | In the historical sources, there is no mention of the raw material worked at Kerczezowitz, however it is certainly the same material as in Podgorce. |

| **Workshop(s):** | Bredezky (3) mentiones a "Bergrath Vampe" as the owner/operator of the gunflint factory at *Krzeszowice* in 1811. An anonymous author (4; *most likely J.G. Hoyer; compare Appendix A, footnote 19*) also refers to the same date (1811), describing the *"Flintenstein-Schlägereien"* (gunflint workshops or knapping places), and especially the precautions of the workers in order to conceal the manufactory's secrets of gunflint production at Krzeszowice. |

| **Reference(s):** | **1)** Slotta 1980, 352; **2)** Seel 1981, 1451; **3)** Appendix A, REF 22; **4)** Appendix A, REF 57; **5)** http://www.plinfo.net/polende/gemeinden/ malopolskie/ krzeszowice.html (4.11.2012). |

1.5. Morawice

Historical name(s): Morawice (1; 2).

Contemp. names(s): Morawica.

Location: Between Kraków and Alwernia,[67] Lesser Poland Voivodship, Powiat Krakowski.

Raw material: Yellow, semi-translucent (equals the French "silex blond").

Workshop(s): At Morawice, in operation around 1820 (1).

Reference(s): 1) Appendix A, REF 23; 2) Appendix A, REF 34.

2. Raw material deposits

Additional to workshops, source regions and important raw material outcrops are also mentioned in historical sources. Some have been used for gunflint production, others were investigated but delivered unsuitable raw material for that purpose.

2.1. Klemboka Dolina *("deep valley")*

Historical name(s): Klemboka Dolina (1).

Contemp. names(s): Uncertain; probably Dolyna (ukr.)/Dolina (pol.).

Location: The location of contemporary Dolyna coincides with Hacquet's indication; a further confirmation is provided by Foetterle 1850, 85.[68] Consequently: "Kreis Stanislawow", former Eastern Galicia; now Ivano-Frankivs'ka Oblast, Ukraine, Dolyna powiat.

Raw material: Black, "priapolithic" shaped[69] flint.

Use of the material: Small scaled exploitation in quarrying pits.

Reference(s): **1)** Hacquet 1792, 36.

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[67] A town 36 west of Kraków, Chrzanów district.

[68] Quote Foetterle 1850, 85: *„Unmittelbar über dem vorhergehenden Gebilde sieht man ebenfalls an den Ufern des Dniesters bei **Dolina** einen weissen, dichten, sehr feinkörnigen Kalk, er ist leicht brüchig, sehr zerklüftet, und leistet der Einwirkung der Atmosphäre wenig Widerstand; in den etwas höher gelegenen Thälern bildet er das tiefste sichtbare Gestein, wie unmittelbar bei Tlumacz, Lokölki und Jezierzany; überall findet man in diesem Kalke eine ungemein grosse Masse Feuersteinknollen, die in dieser Gegend früher das Material zu den Flintensteinen lieferten."*

[69] Dézallier D'Argenville 1772, register in the appendix (Alphabetisches Verzeichnis vieler schwerer und unbekannter sowohl lateinischer, als aus dem Griechischen genommener Wörter), pg. XLV: *„Priapolithos, Priapolite, Stein, der den Naturgliedern eines Mannes gleich siehet."*

2.2. Mariampol (Marianopol)

Historical name(s): Mariampol (1; 2); Marianopol (3; 4).

Contemp. names(s): Mariiampil (previously: Marynopil).

Location: A village (a former township) in the former "Kreis Stanislawow", Eastern Galicia; now Ivano-Frankivs'ka Oblast, Ukraine, Halych Rajon, on the left bank of the Dnjestr.

Raw material: Not specified.

Use of the material: See 1.2. Nizniow.

Reference(s): **1)** Appendix A, REF 5; **2)** Liechtenstern 1817, 1188; **3)** Appendix A, REF 24; **4)** Fränzl 1841, 339.

2.3. Lichostiwne

Historical name(s): Lichostiwne (1; 2).

Contemp. names(s): Unknown.

Location: A mountain/hill in Eastern Galicia, close to the River Dnjestr. Present day Ukraine.

Raw material: Blackish-brown and grey flint, imbedded into whitish-grey, marly limestones. Hacquet (1806/1, 99) mentions five layers of flint, of which the third layer was most productive and suitable for gunflint production.

Use of the material: Extraction in quarrying pits, located at the outcrops of the flint layers mentioned above (illustration in Hacquet 1806/2, plate 1).

Reference(s): **1)** Hacquet 1806/1, 99-100; **2)** Hacquet 1806/2, 13.

2.4. Zaleszczyk

Historical name(s): Zaleszczyk (1).

Contemp. names(s): Probably Zaleszczyki; Salischtschyky (ger.)

Location: *If Zaleszczyk is identical with the contemporary Zaleszczyki:* Former Eastern Galicia; now Ternopli Oblast, Ukraine, Zaleszczyk Rajon, located at the River Dnjestr.

Raw material: Black and grey flint.

Use of the material: Not specified.

Reference(s):   **1)** Hacquet 1790, 49.

2.5. Zapronci-Mountains

Historical name(s): Zapronci Gebirge (1; 2)

Contemp. names(s): Unknown.

Location: Hacquet (1806/1, 98-99) states: "The first mountain range thereat (i.e. Nizniow) containing flint nodules was known under the name Zapronci. () These mountains were located several Podolian miles[70] from the factory." Consequently, these mountain ranges are situated in the former "Kreis Stanislawow", Eastern Galicia; now Ivano-Frankivs'ka Oblast, Ukraine,

Raw material: An abundance of flint nodules, accumulated at the bottom of a ravine; residual/secondary surface deposits (1).

Use of the material: Raw material from sources in the Zapronci Mountains was delivered to Nizniow during the early times of the gunflint factory (see **1.2. Nizniow**). Because these raw material sources were remote from the workshops, the flint nodules were prepared on site (cleaving and blade production). According to Hacquet (1806/1, 99), this was the only source region in Galicia where this technique was applied. However, the exploitation of these deposits only lasted for one summer and was ceased due to unprofitability.

Reference(s):   **1)** Hacquet 1806/1, 98-99; **2)** Hacquet 1806/2, 12-13.

2.6. Zbrycz

Historical name(s): Zbrycz (1; 2).

Contemp. names(s): The only similar contemporary toponym is the River Zbrucz (pol.); Sbrutsch (ger.).[71]

Location: According to Hacquet (1790, 38), sources are located at the Pole-górne hill (not traceable).

Raw material: Hacquet (1790, 38) refers to white, grey and blackish flint, mostly non translucent, but suitable for gunflint production.

Use of the material: Not specified.

Reference(s):   **1)** Hacquet 1790, 38; **2)** Hacquet 1792, 30, 39.

---

[70] The best convergance to "Podolian miles" is the Russian measurement unit: 1 russian mile (7 werst) = ca. 7,5 km.
[71] However, Hacquet's Zbrycz seems to be the name of a village or town. No reference to a place with a similar name was found in contemporary Poland and Ukraine.

2.7. Podolian sources east of the Podhorce/Zbrycz river

Historical name(s): Podhorce/Zbrycz (1; 2).

Contemp. names(s): See **2.6. Zbrycz.**

Location: East of the Podhorce/Zbrycz River[72] (2). The sources were probably situated along the river banks of the Zbrucz, a tributary river to the Dnjestr in western Ukraine. In the 18th century, the territory was located outside the Austrian territories, in the Republic of Poland (later in czaristic Russia).

Raw material: Hacquet (1792, 39) mentions yellowish flint with a white cortex at the Podhorce/Zbrycz River, considering this material the "real flintstone" (comparable to the French "silex blone"); however, this flint variety is very rare in Galicia.

Use of the material: Not specified.

Reference(s): **1)** Hacquet 1790, 38; **2)** Hacquet 1792, 30, 39.

2.8. Summary of additional (small) outcrops in Eastern Galicia

Historical name(s): Na-Rinwach, Babyowa, Grabek, Doremowka, Babrownikami, Sredni-Garb (1; 2).

Contemp. names(s): Investigations concerning these historical names only revealed very dubious results.

Location: Hacquet (1806/1, 99) cites the above mentioned locations in company with the Lichostiwne Mountain (see **2.3. Lichostiwne**). Hence, it is very likely that these outcrops are situated in the same area, in Eastern Galicia, close the River Dnjestr, present day Ukraine.

Raw material: Presumably very similar to the raw material from the Lichostiwne Mountain.

Use of the material: Not specified.

Reference(s): **1)** Hacquet 1806/1, 99; **2)** Hacquet 1806/2, 13**.**

---

[72] Podhorce river = Zbrucz river (Meyers Grosses Konversations-Lexikon, 6. Auflage, 1905-1909, " Zbrucz"). However, Zbrycz seems to have been a village or town. No reference to a place with a similar name was found in contemporary Poland and Ukraine.

2.9. Sources in the "Sobotian Ukraine"

Historical name(s): Not specified.

Contemp. names(s): Not specified.

Location: Hacquet (1806/1, 27) locates deposits "…on the far side of the Dnjepr, towards Charkow ."[73]

Raw material: Wedge-shaped flint splinters scattered on the surface.

Use of the material: Used by the locals on their guns, without any further processing.

Reference(s):   **1)** Hacquet 1806/1, 27.

---

[73] Contemporary Charkiw, Charkiw Oblast (ger.: Kharkiv; rus.: Charkow), 2nd biggest town in Ukraine.

Appendix C: Tables for the Chert Group Classification System

	material	name	type	petrological genesis	structure	genesis
	quartz	historic	mineral	primary igneous; can be of metamorphic or sedimentary origin	rough-fine-crystalline	inorganic
	chalcedony	historic	mineral	chemical sedimentary, hydrothermal	cryptocrystalline	inorganic
	jasper	historic	mineral	chemical sedimentary, hydrothermal	cryptocrystalline	inorganic
	agate	historic	mineral	hydrothermal	cryptocrystalline	inorganic
chert - group	**flint**	**historic**	**rock**	**sedimentary (Cretaceous)**	**crypto-microcrystalline**	**organic**
	chert	**depending on fossil content**	**rock**	**sedimentary (Jurassic)**	**crypto-microcrystalline**	**organic**
	silicified limestone	**according to the rock consistence**	**rock**	**sedimentary**	**fine-crystalline**	**organic**
	lydite	**historic**	**rock**	**metamorphic (origin: sedimentary rocks)**	**fine-crystalline**	**mainly organic**
	opal	historic	mineral	metamorphic, sedimentary or hydrothermal	amorphous, partly crystalline	inorganic/ organic
	petrified wood	referring to the source material	mineral (if petrified by quartz or opal)	Pseudomorphosis	depending on petrifying material	inorganic/ organic
	obsidian	historic name of a person (*Obsius*)	igneous glass	igneous	amorphous, rarely partly crystalline	inorganic
	tectite	referring to an event	impact glass	impact of a meteorite	amorphous	inorganic
	quartzite	referring to the source material	rock	metamorphic	rough-fine-crystalline	inorganic

Table AC 1: Lithic raw materials used for stone tool production
Graph: M. Brandl.

Chert Group Classification System I: Chert

genesis		**generally Jurassic**	**sometimes Cretaceous**
fissures	yes	often	
	no	rarely	
fracture properties		Conchoidal-smooth	
		Amorphously-rough	
granularity		very rough-very fine grained	
carbonate content	yes	not always detectable	
		highly calcareous	**siliceous limestone**

matrix		silicified				
inclusions	fossil	fossil type	count			
			0%	< 10%: Index fossilisation detectable		
		A.a radiolaria	**chert**	**radiolarite**		
		A.b spicula	**chert**	**spiculite**		
		A.c sponges remains	**chert**	**spongiolite (spongilite)**		
		A.d crinoidea	**chert**	**chert**		
		A.e foraminifera	**chert**	**chert**		
		A.f seashells	**chert**	**chert**		
		A.g detritus	**chert**	**chert**		
	non - fossil	type	count			
			none	some	many	very many
		A.a. heavy minerals (garnett, tourmaline,…)	x	x	x	rarely
		A.b. mica	x	x	x	rarely
		A.c. quartz geodes	x	x	x	x
		A.d. SiO_2-precipitations	x	x	rarely	very rarely
		A.e. various foreign minerals	x	x	x	x
	none	no (detectable) inclusions				

metamorphic genesis layered structure black colour dense matrix	**lydite**

Table AC 2: Classification system for members of the chert-group
Graph: M. Brandl.

Chert Group Classification System II: Flint

genesis		**Cretaceous**
fissures	yes	rarely
	no	often
fracture properties		conchoidal-smooth
granularity		very fine grained
carbonate content	yes	in the cortex
	no	in the matrix
matrix		very densly silicified

Inclusions	fossil	fossil type	count		
			0%	many	very many
		A.a radiolaria	always	never	
		A.b spicula	rarely	often	possible-rarely
		A.c sponges remains	rarely	often	possible-rarely
		A.d crinoidea	often	possible	possible-rarely
		A.e foraminifera	often	possible-often	possible-rarely
		A.f seashells	possible	possible-rarely	possible-rarely
		A.g detritus		often	possible-rarely
	non fossil	type	count		
			none	some	many	very many
		A.a. heavy minerals (garnet, tourmaline,…)	always	never	never	never
		A.b. mica	always	never	never	never
		A.c. quartz geodes	possilbe	possible	rarely	rarely
		A.d. SiO_2-precipitations	often	often	possible	possible
		A.e. various foreign minerals	possible	rarely	very rarely	very rarely
	none	no inclusions			

Table AC 3: Classification system for flint
Graph: M. Brandl.

Appendix D1: Comparative raw material sources

1. Raw material varieties from the comparative sources

1.1. Rein

Photos: D. Modl

1.2. Baiersdorf

Photos: G. Trnka

1.3. Feuersteinmähder

1.4. Rothornjoch

1.5. Grubalacke

1.6. Elsbethen/ Glasenbachklamm

1.7. Wien Mauer

Photos: G. Trnka

1.8. Wien Gemeindeberg

1.9. Nemšová Kamenice

1.10. Vlára-Bolešov

1.11. Vršatské Podhradie
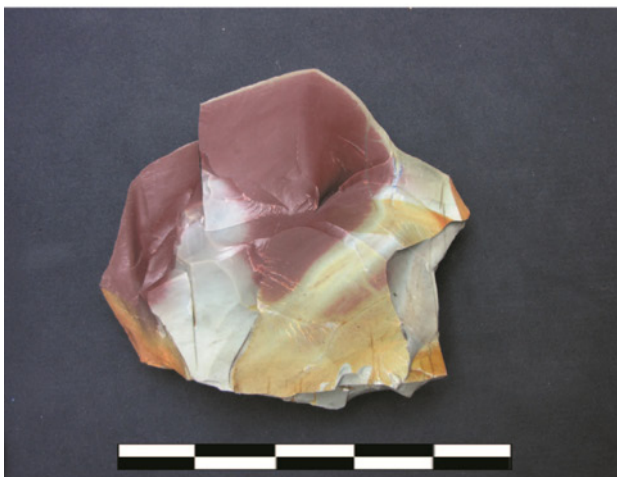
1.12. Falsztynski Potok

1.13. Meusnes

1.14. Ceredo

1.15. Bębło

1.16. Mników

1.17. Czajowice

1.8. Sąspów

2. Macrophotos of the sampled raw materials

This Section provides the range of raw material present in the sampled comparative sources. Although most sampled specimens are represented, the smaller samples had to be mounted as a whole.
Due to the fact that multiple sampling sessions were conducted, the same sample number may occur for different samples. A clear link between those samples and the geochemical results is provided in Appendix D4 (sample inventory). Photos without citation were taken by M. Brandl.

2.1. Baiersdorf

2.2. Rein

2.2.1. Tabular chert

2.2.2. Nodular chert: Rein 6 (7)
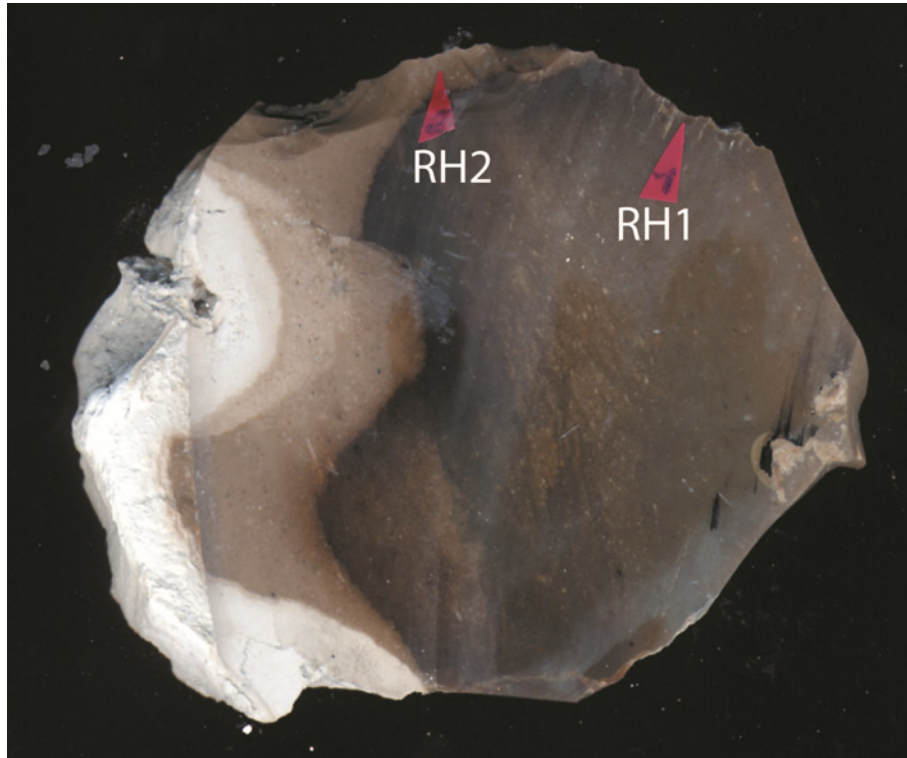
2.2.3. Nodular chert: Rein 8

2.3. Feuersteinmähder

2.4. Rothornjoch

2.5. Grubalacke

2.6. Elsbethen/Glasenbachklamm

2.7. Wien Mauer

2.8. Wien Gemeindeberg

2.9. Nemšová Kamenice

2.10. Vlára-Bolešov

2.11. Vršatské Podhradie

2.12. Falsztynski Potok

2.13. Meusnes
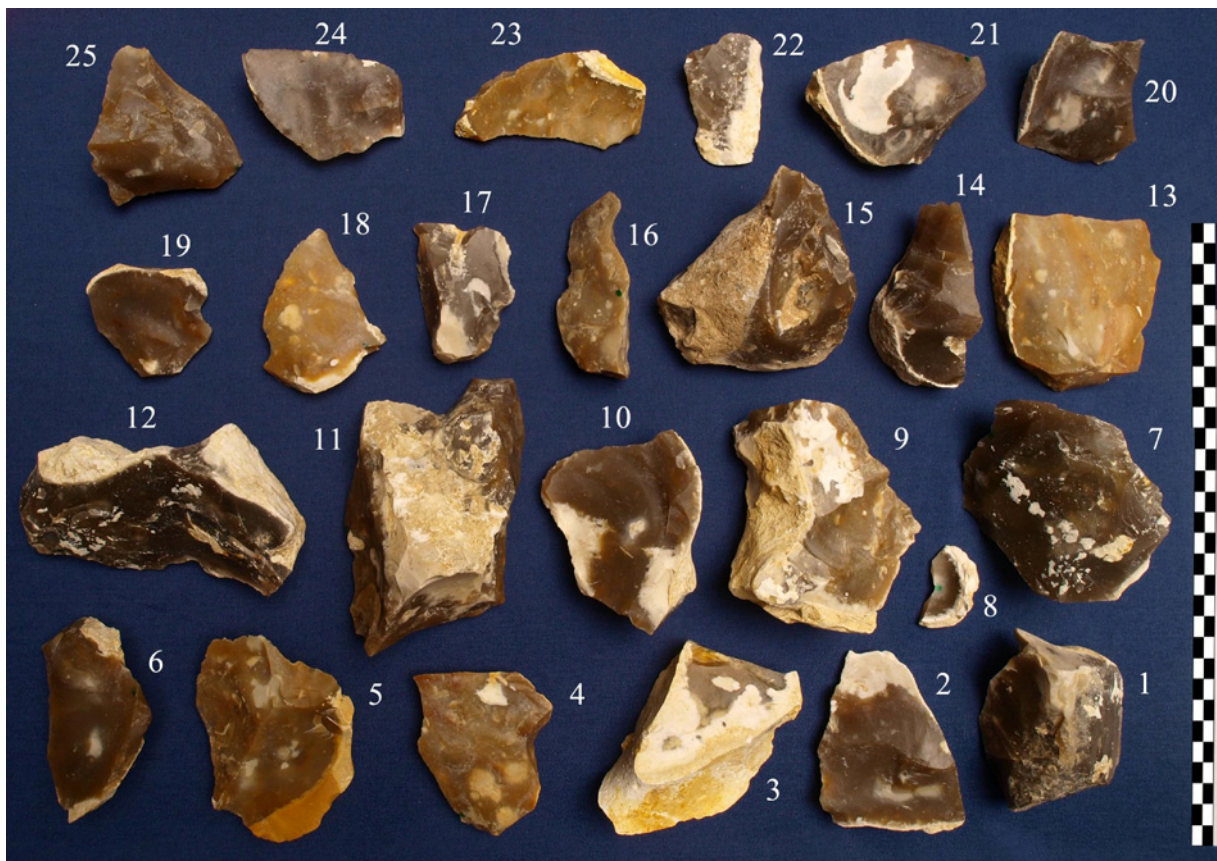
2.14. Bębło

2.15. Mników

2.16. Czajowice

2.17. Sąspów
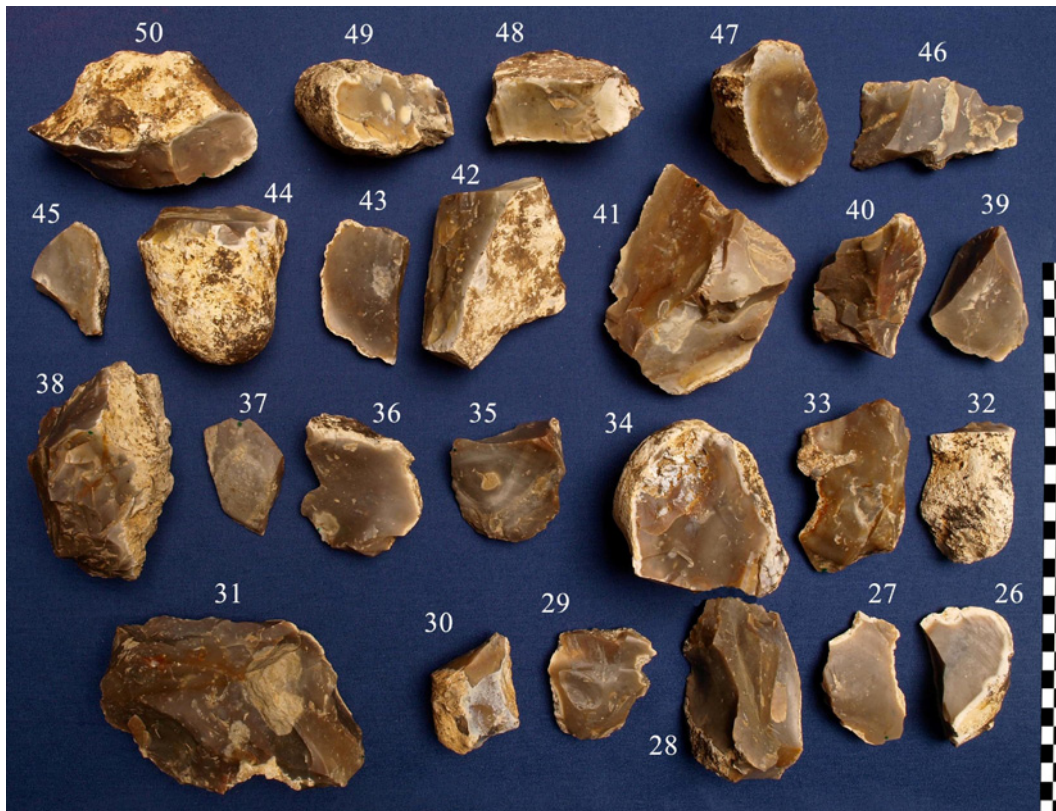
2.18. Ceredo
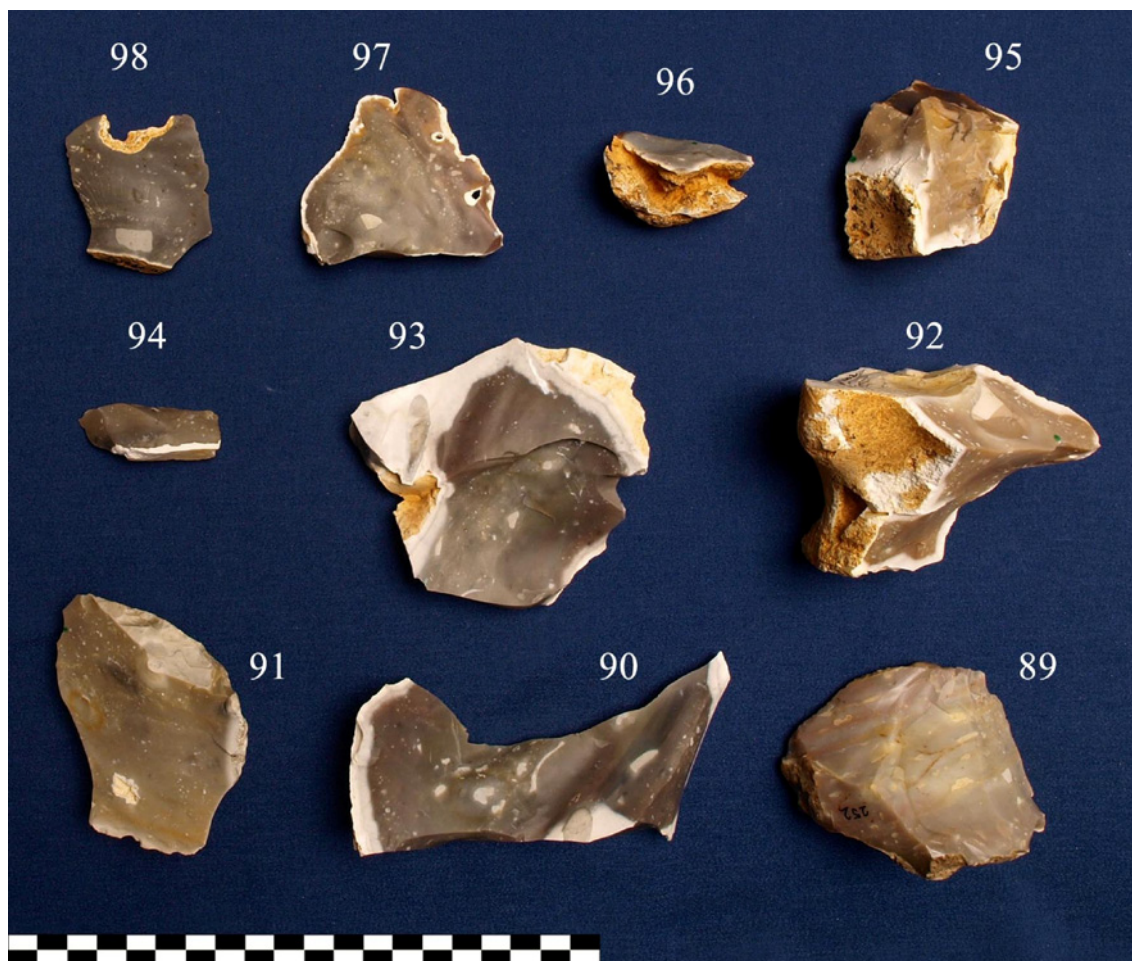
2.19. Sant' Anna D'Alfaedo

3. Microphotos

3.1. Rein
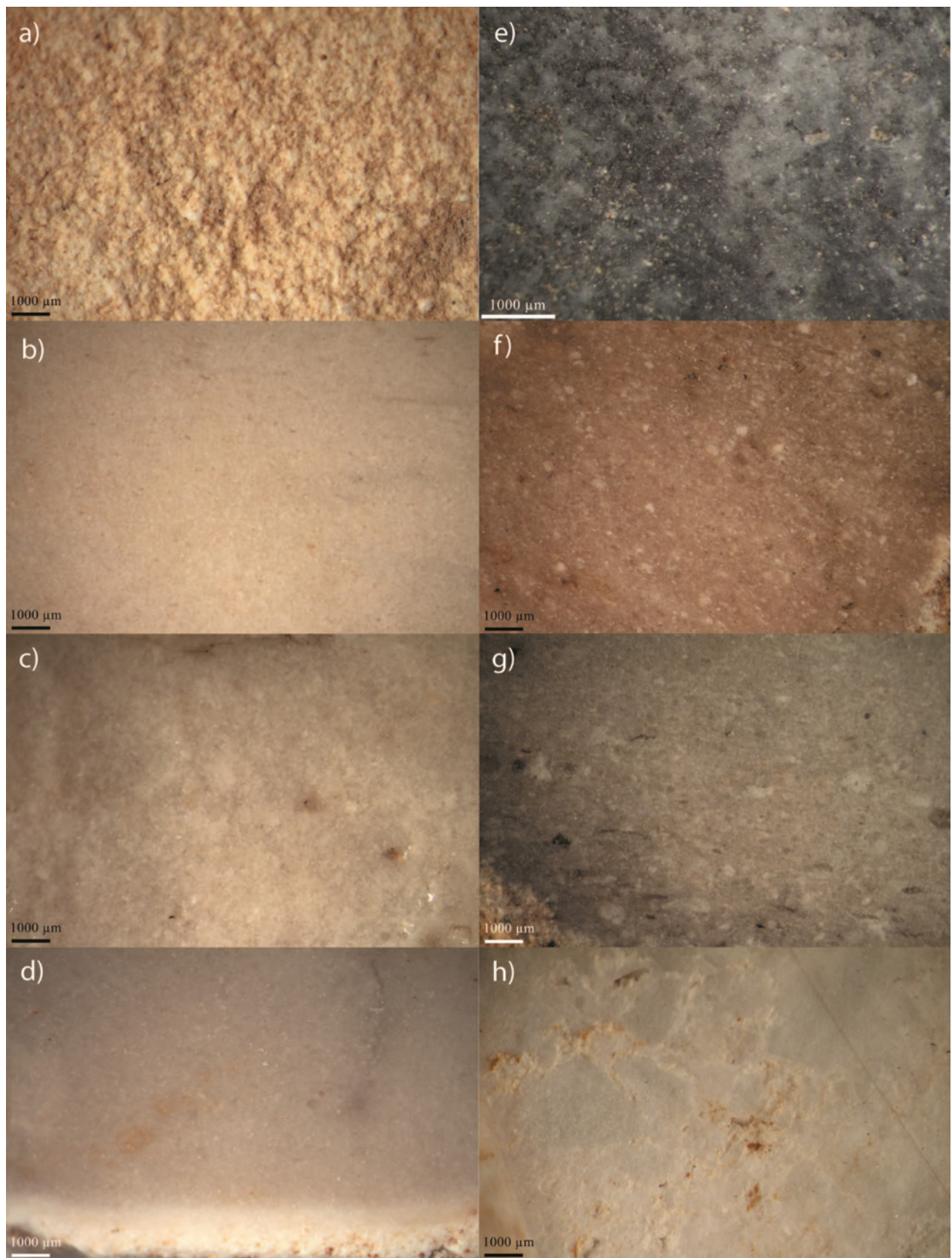
Key: a: Rein I; b: Rein II; c: Rein III; d: Rein IV; e: Rein V; f: Rein 6; g: Rein 7; h: Rein 8.

3.2. Baiersdorf
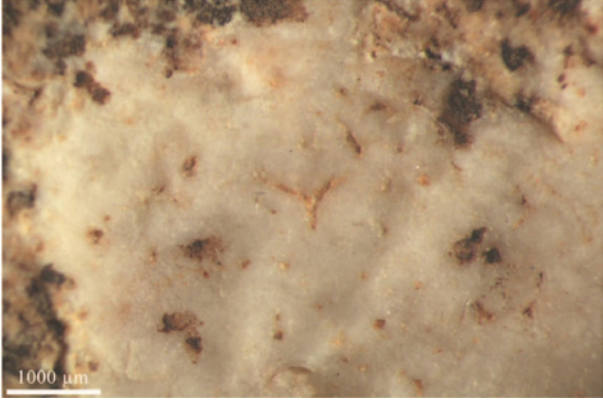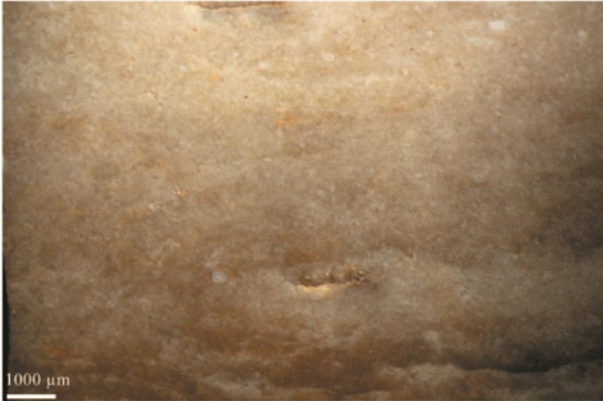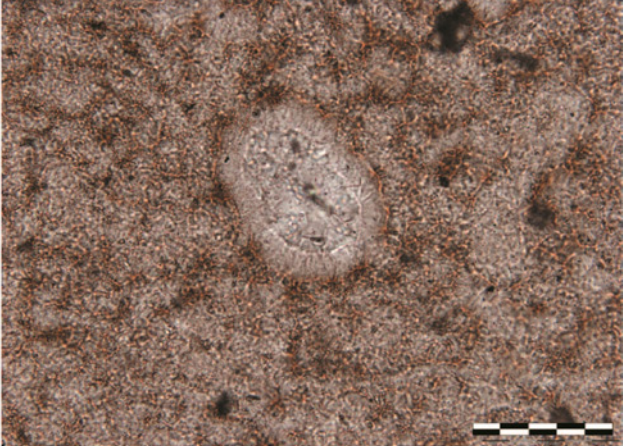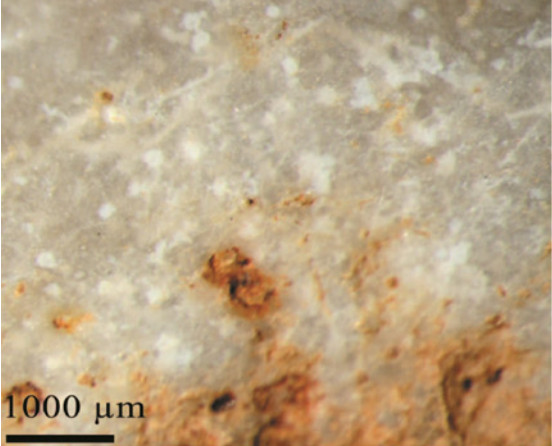
3.3. Radiolarites
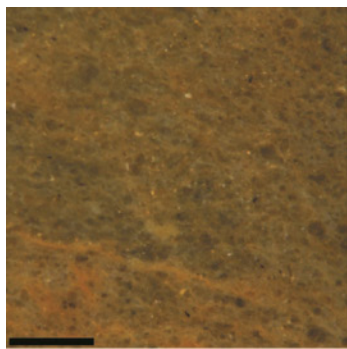
Feuerstein-mähder
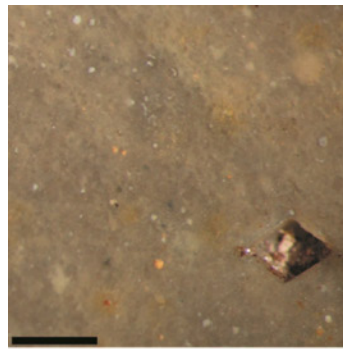
Wien Gemeindeberg
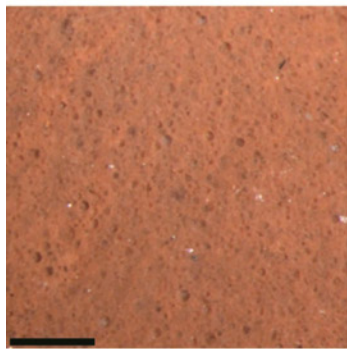
Rothornjoch
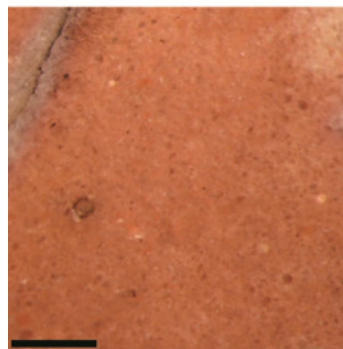
Nemšová Kamenice
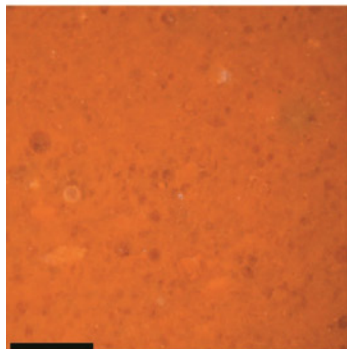
Grubalacke
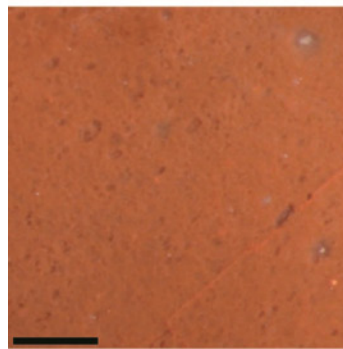
Vlára-Bolešov
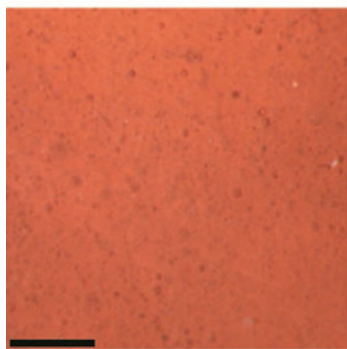
Elsbethen/ Glasenbach-klamm
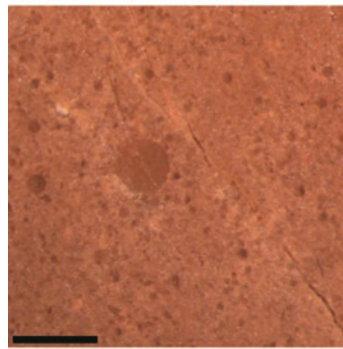
Vršatské Podhradie
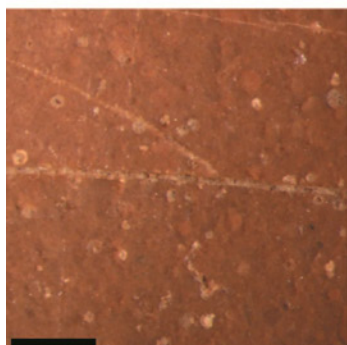
Wien Mauer

Falsztynski Potok
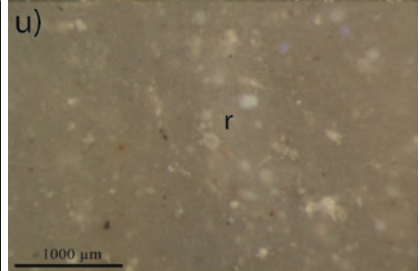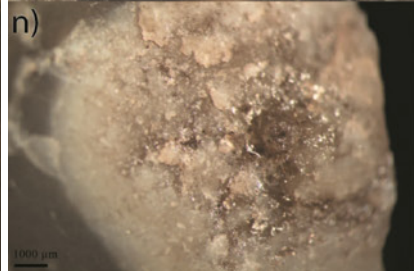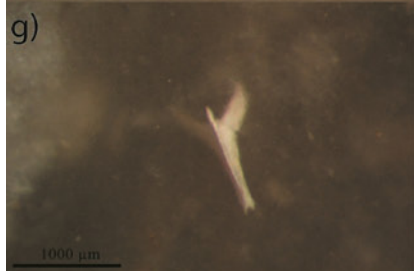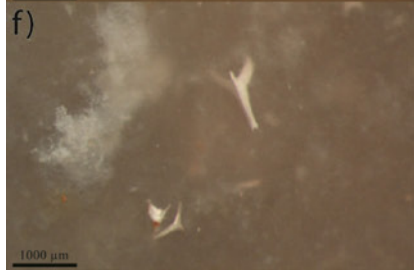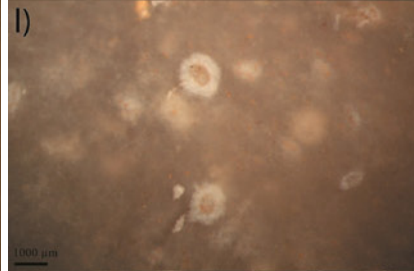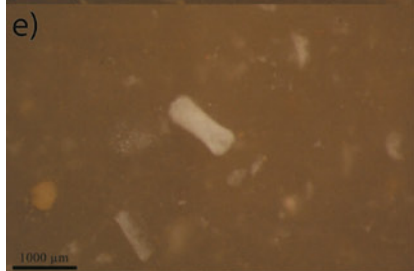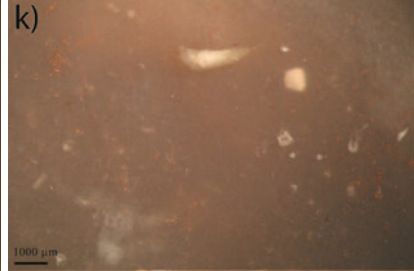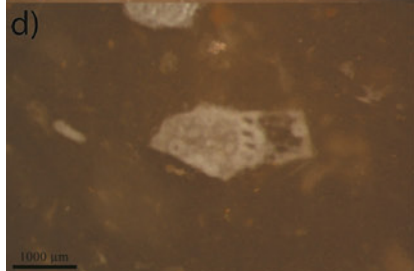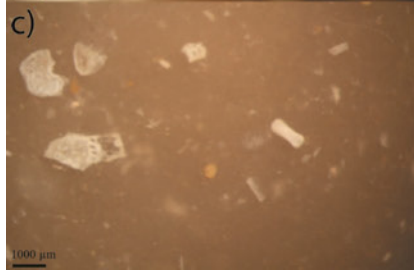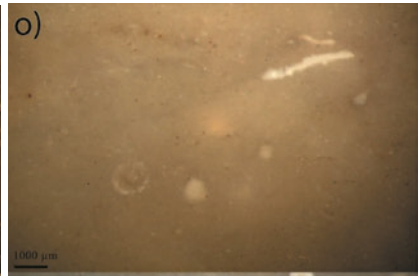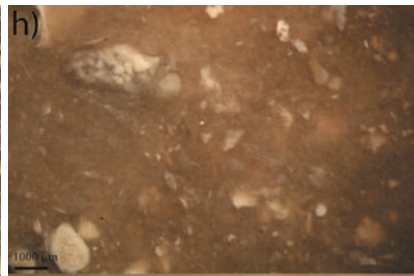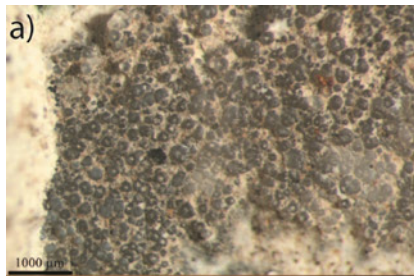
Appendix D2: Sampled artifacts

1. Macrophotos

For the Rein versus Baiersdorf case study, only selected representative artifacts from Styrian sites are presented. In the case of the radiolarites and the gunflint investigations, all analysed specimens are depicted.

1.1. Repolust Cave: selected artifacts

← Inv.No. 15327

Inv.No. 15618 →

← Inv.No. 15410

Inv.No. 15679 →

← Inv.No. 15411

Inv.No. 15820→

← Inv.No. 15450

Inv.No. 16105 →

← Inv.No. 15500

Inv.No. 24845 →

← Inv.No. 15616

Inv.No. 24850 →

Photos: D. Modl

Photos: D. Modl

1.2. Tunnel Cave and Zigeuner Cave: selected artifacts

← Inv.No. 23649

Inv.No. 12471 →

← Inv.No. 23650

Inv.No. 12472 →

← Inv.No. 23654

Inv.No. 12480 →

← Inv.No. 23655

Inv.No. 12485 →

← Inv.No. 12464

← Inv.No. 12465

Tunnel Cave:
Inv.No. 23649, 23650, 23654, 23655

Zigeuner Cave:
Inv.No. 12464, 12465, 12471, 12472, 12480, 12485

Photos: D. Modl

1.3. Raababerg (Neolithic) and Grötsch (Early Medieval): selected artifacts

← Inv.No. R 164

Inv.No. R 840 →

← Inv.No. R 350

Inv.No. R 848 →

← Inv.No. R 784

Inv.No. 18587 →

← Inv.No. R 786

Inv.No. 18588 →

Raababerg:
Inv.No. R 164, R 350, R 784, R 786, R 840, R 848

Grötsch:
Inv.No. 18587, 18588

Photos: D. Modl

1.4. Radiolarites from Krems-Wachtberg

WA 7724	WA 17913
WA 7770	WA 68497
Wa 7782	Wa 74327
WA 8183	WA 87982/46
WA 8640/31	
WA 15354	
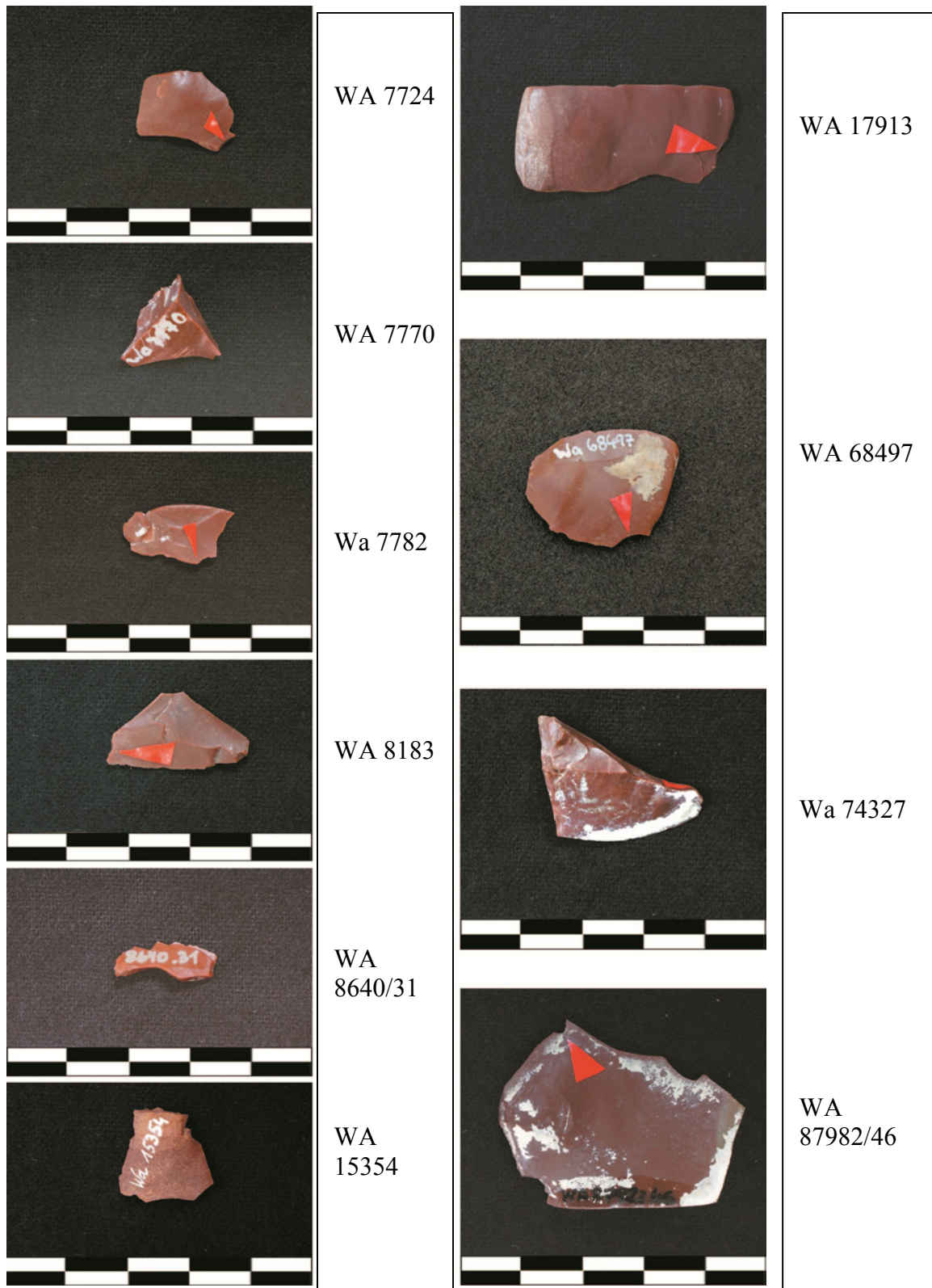
1.5. Gunflints from Schloss Neugebäude

2. Microphotos

For the Rein versus Baiersdorf case study, again only a selection of representative artifacts is presented. This involves specimens from the Repolust Cave site. Microphotos of all sampled radiolarite artifacts and gunflints are provided. All microphotos were taken by M. Brandl.

2.1. Repolust Cave: selected artifacts
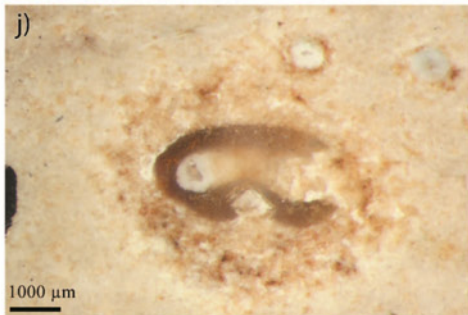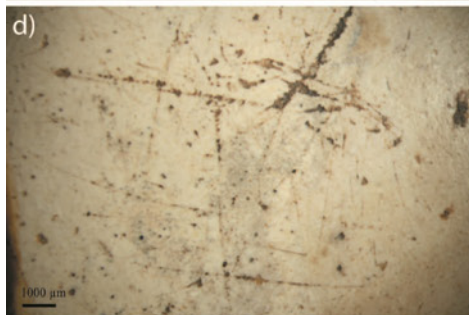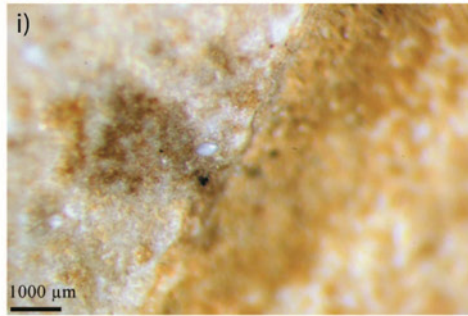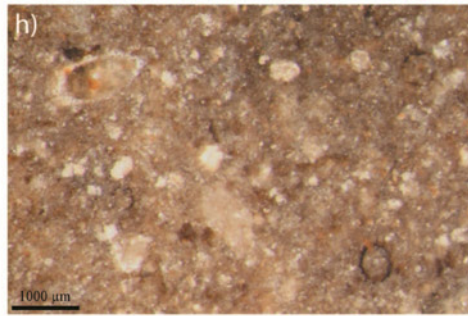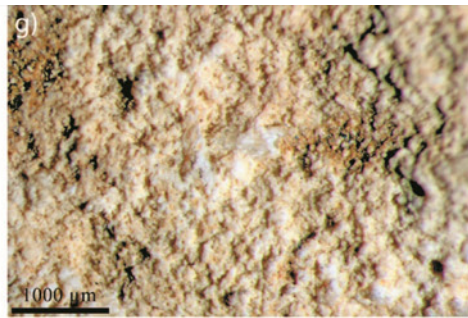
a: Inv.No. 15500
texture Rein 7

b: Inv.No. 16105
texture Rein 6
translucent

c: Inv.No. 15589
chalcedony vein

d: Inv.No. 15616
scratched surface

e: Inv.No. 15749
texture Rein 7

f: Inv.No. 15942
texture Rein 7

g: Inv.No. 16022
charophyte remain
in cortex

h: Inv.No. 24723
charophyte
sections

i: Inv.No. 24752
ostracode
inclusion

j: Inv.No. 24845
charophyte
inclusion

k: Inv.No. 24850
"chert pest"

l: Inv.No. 24852
texture Rein 7

2.2. Radiolarites from Krems-Wachtberg

a: WA 7724	
b: WA 7770	
c: WA 7782	
d: WA 8183	
e: WA 8640/31	
f: WA 15354	
g: WA 17913	
h: WA 68497	
i: WA 74327/29	
j: WA 87982/46	
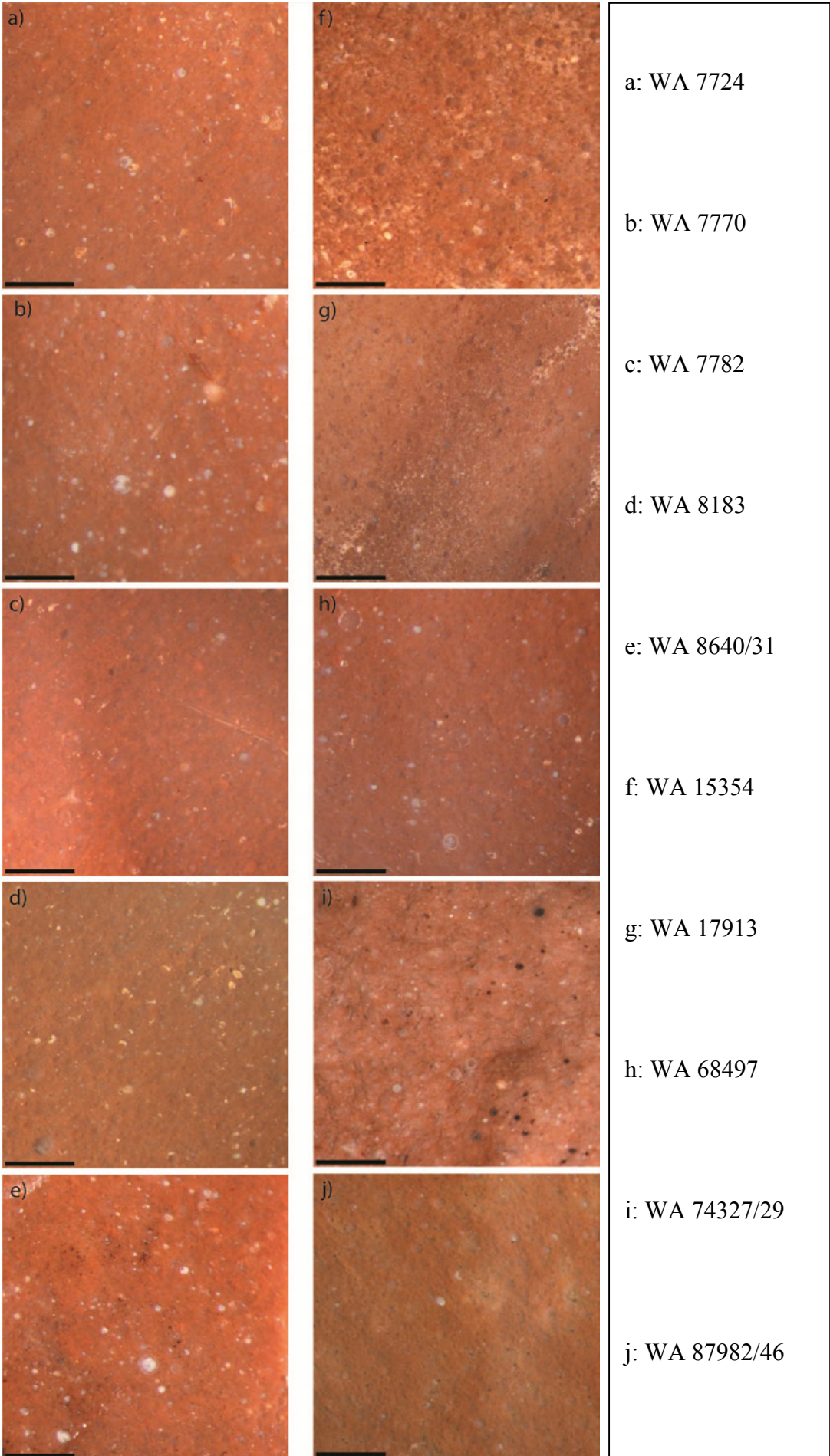
2.3. Gunflints from Schloss Neugebäude I (Lessini flint)

a: 239

b: 239

c: 240

d: 241

e: 242

f: 243
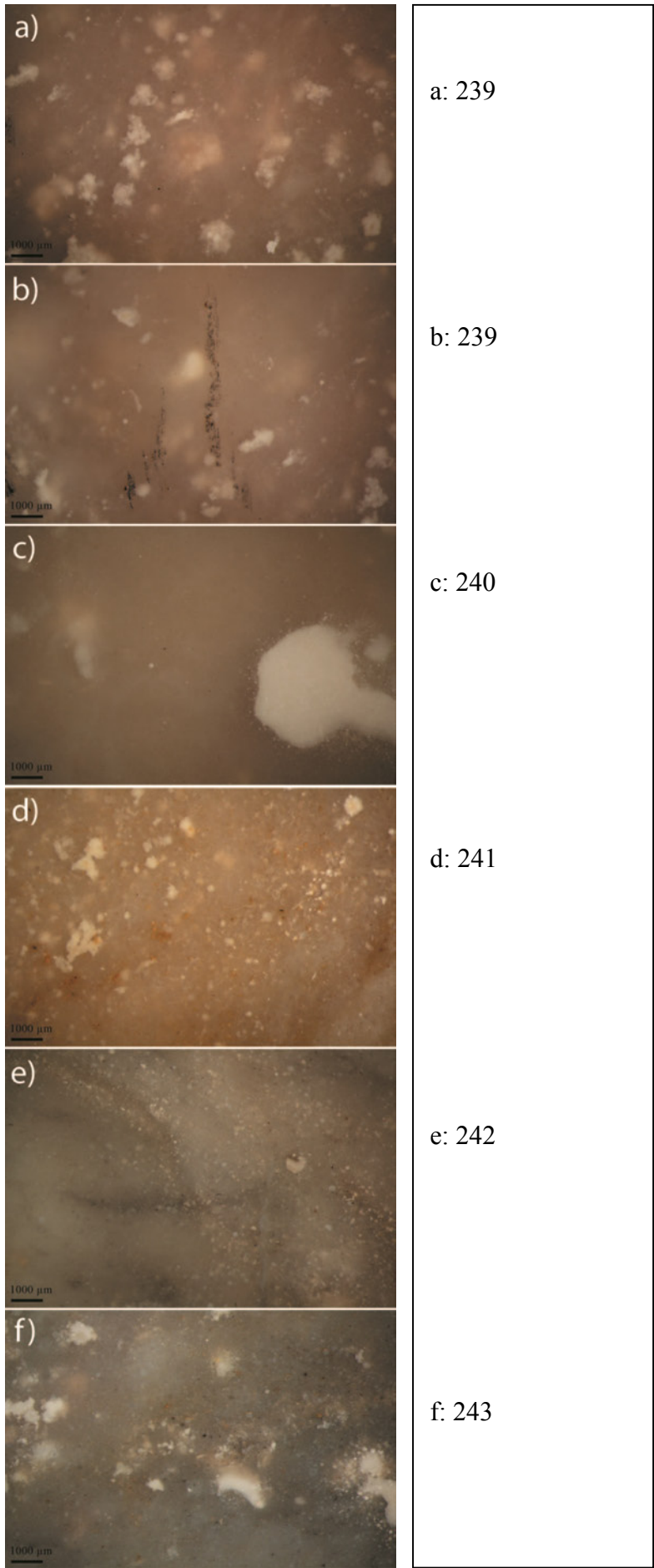
2.4. Gunflints from Schloss Neugebäude II (Meusnes flint)

g: 234

h: 234

i: 235

j: 236

k: 237

l: 238
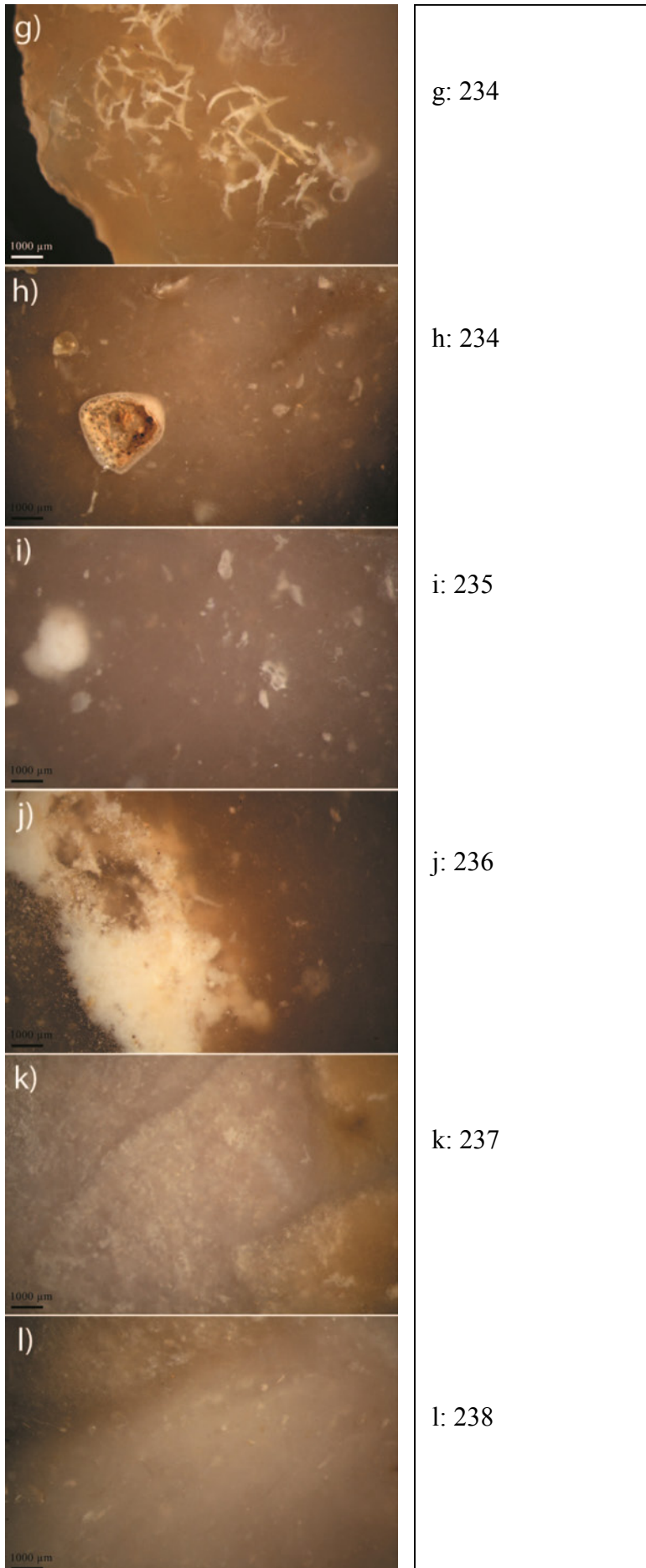
2.5. Gunflints from Schloss Neugebäude III (suspected Kraków "flint" = Meusnes flint)

m: 244

n: 245

o: 246

p: 247

q: 248

r: 248
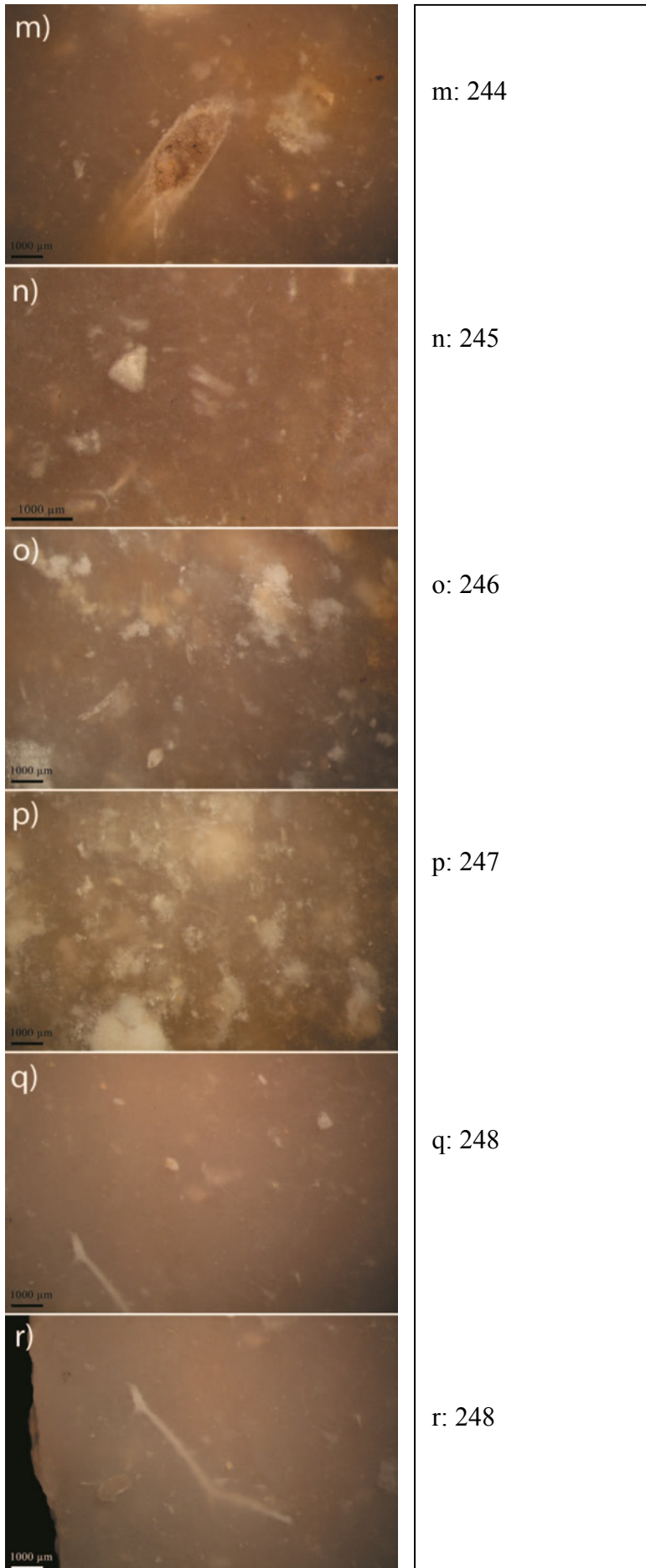
Appendix D3: Mounts for LA-ICP-MS analysis

Some Mounts contain samples that are not part of the Dissertation. They are not present in Appendices D1 and D2. Red numbers indicate samples that did not preserve in the course of polishing and were therefore not analysed.

Mount R (Rein)

Mount B (Baiersdorf)
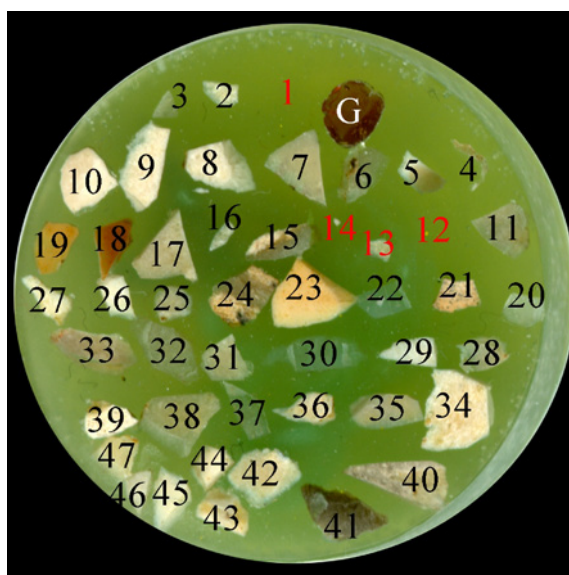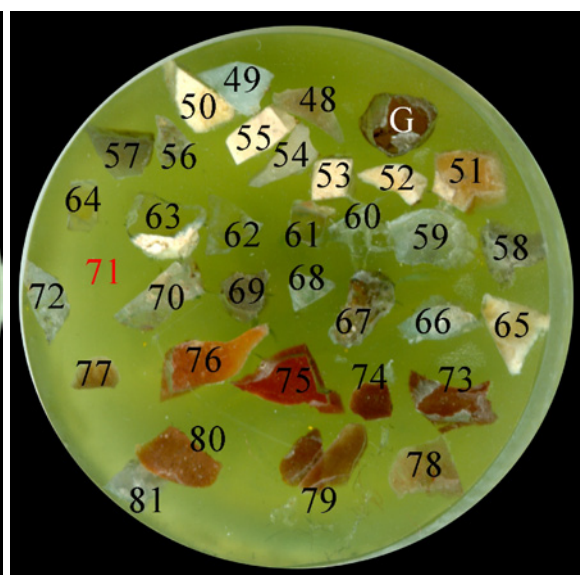
Mount A

Mount B

Mount 1
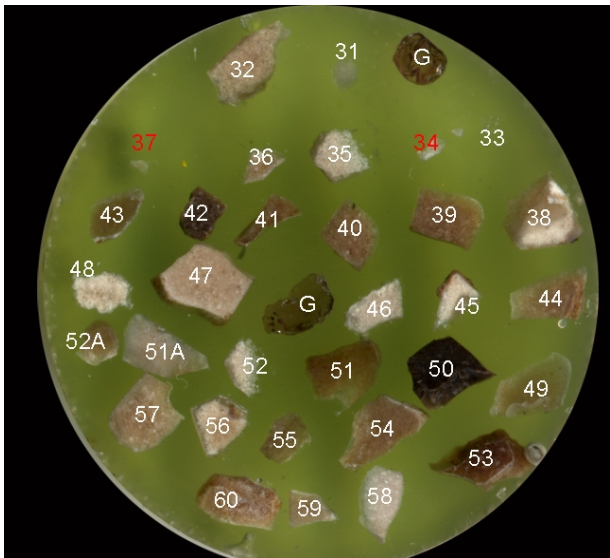
Mount 2
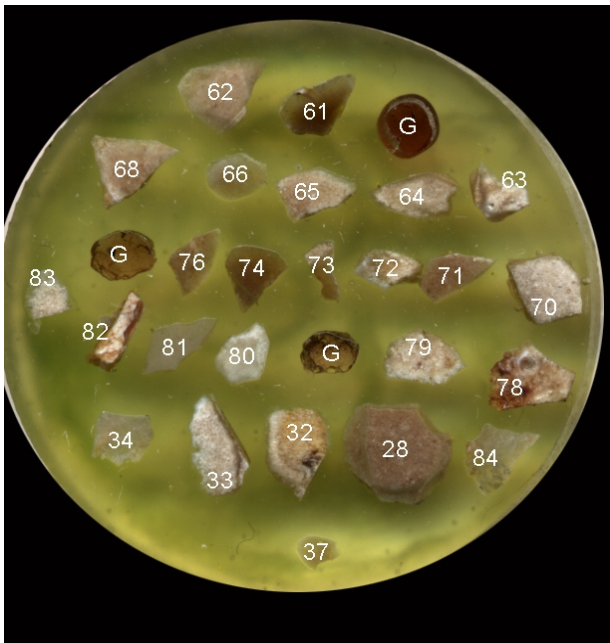
Mount 3
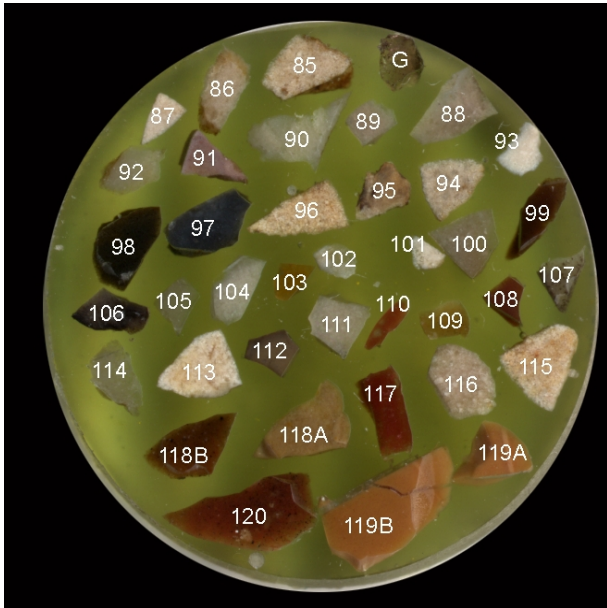
Mount 4

Mount 5

Mount MJ
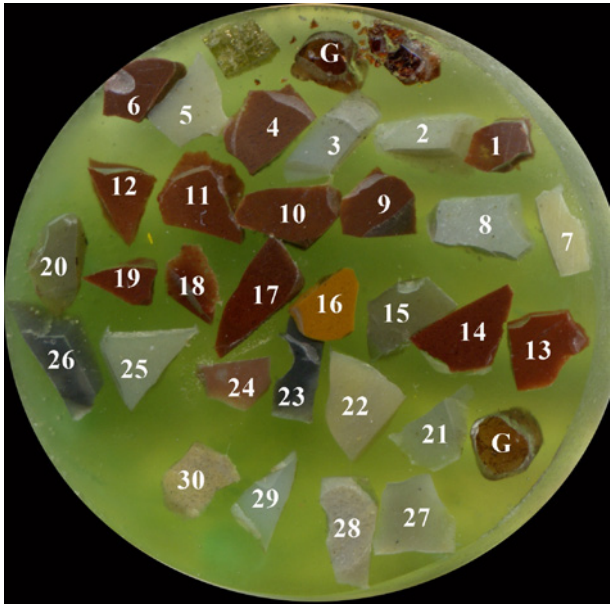
Mount WP 1
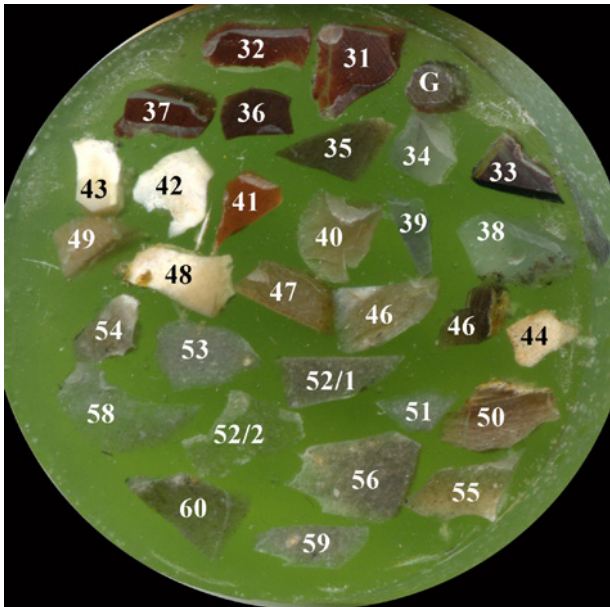
Mount WP 2
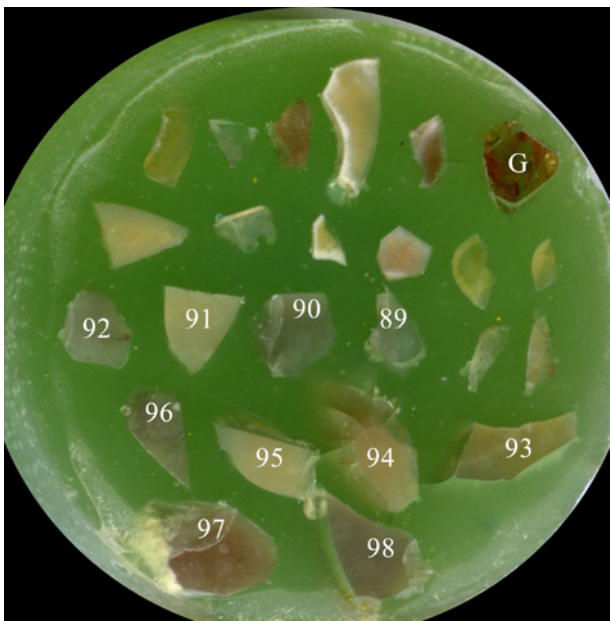
Mount MB 1
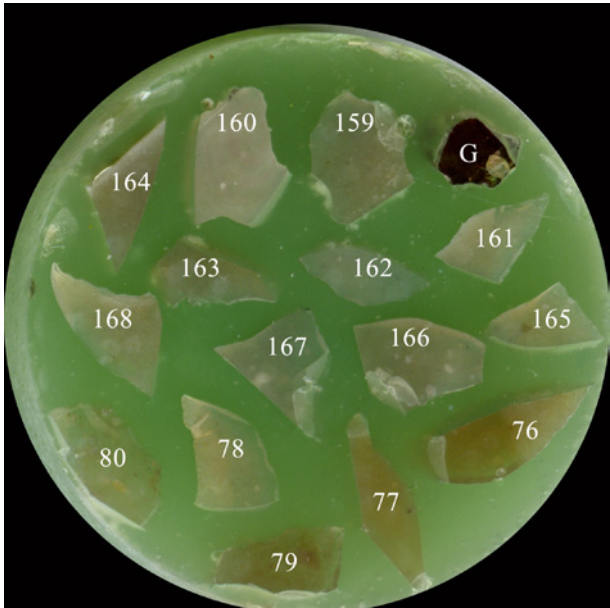
Mount MB 2
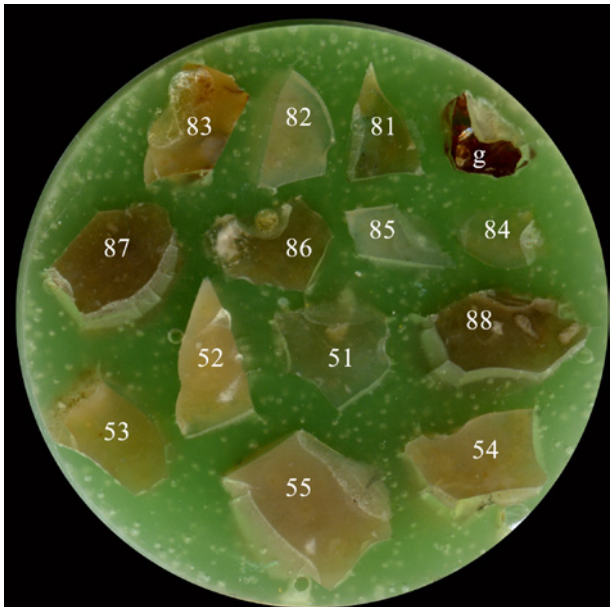
Mount MB 3
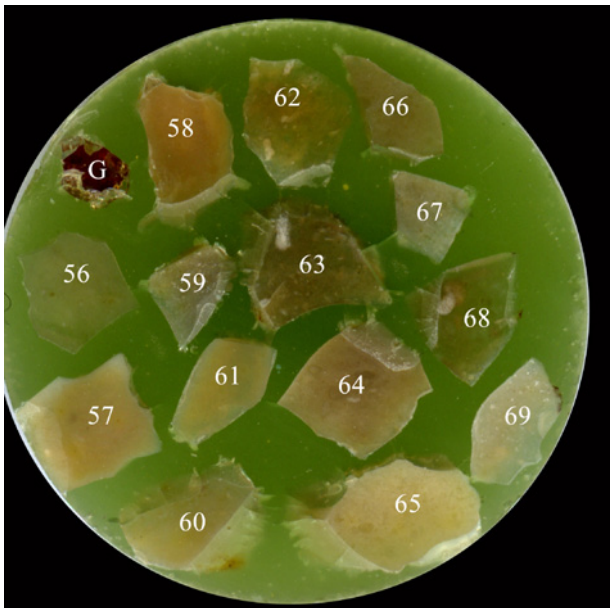
Mount MB 4
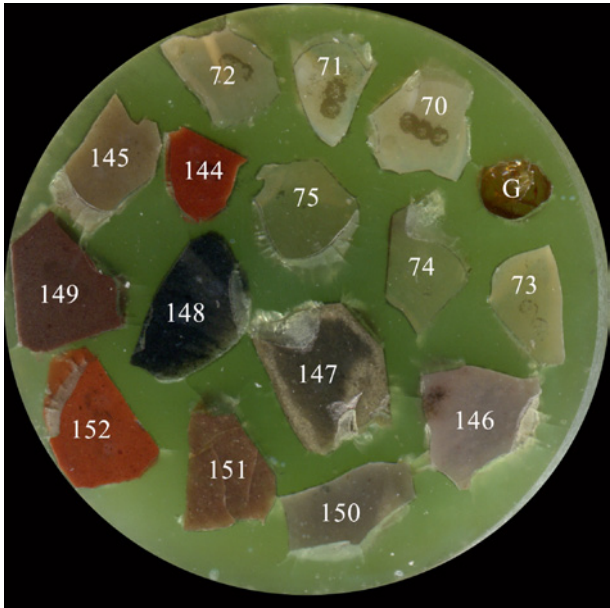
Mount MB 5
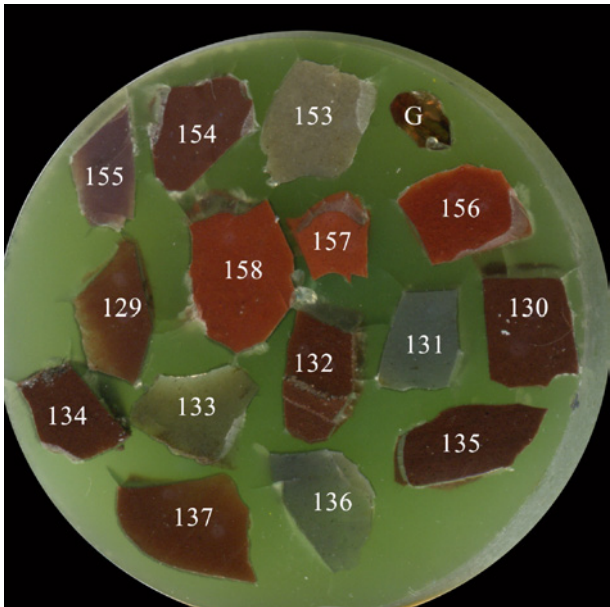
Mount MB 6
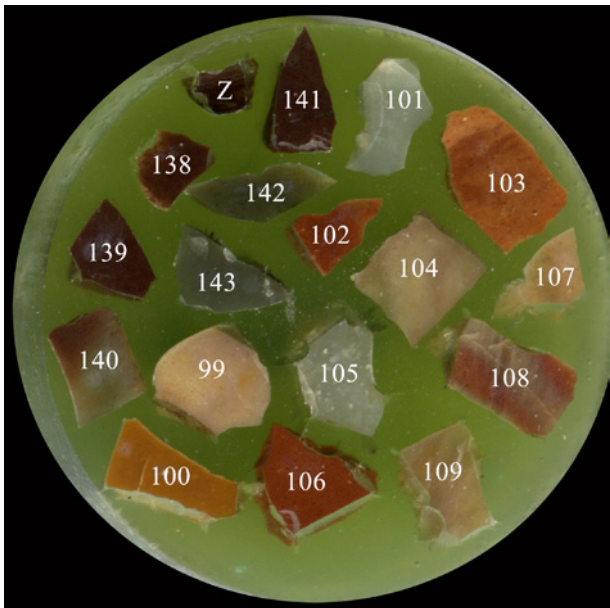
Mount MB 7
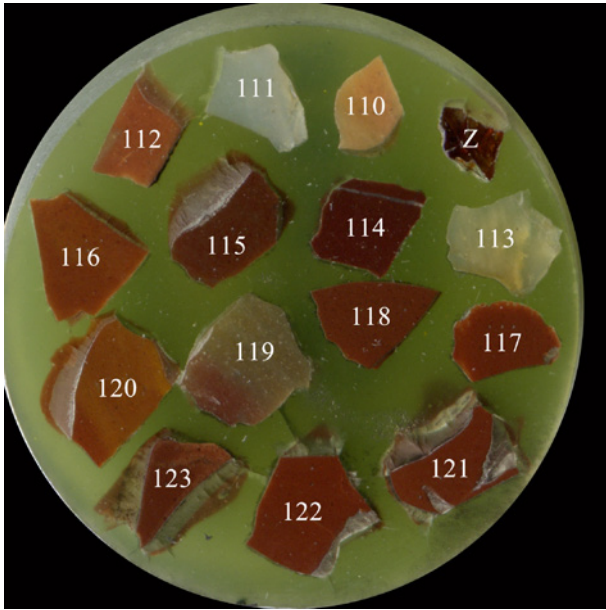
Mount MB 8
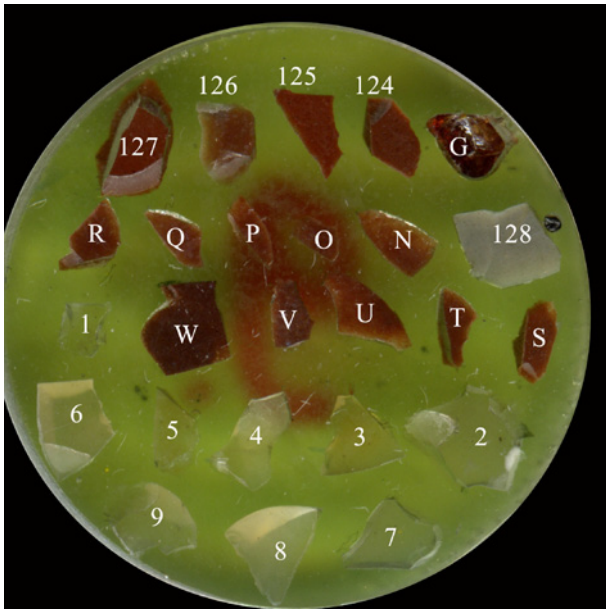
Mount MB 9
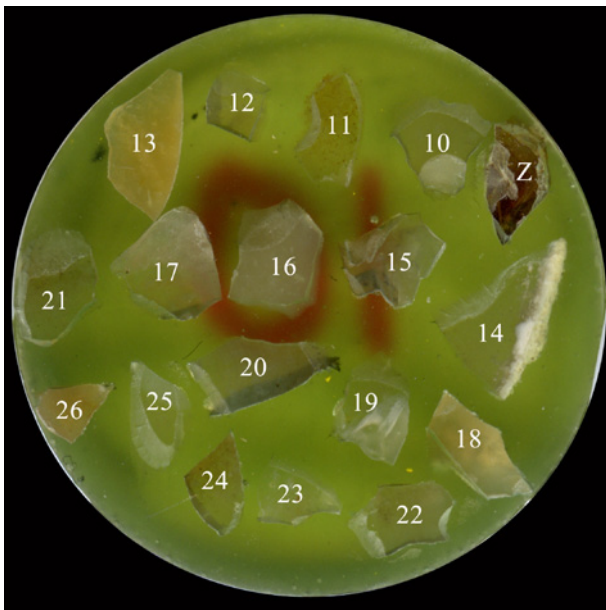
Mount MB 10
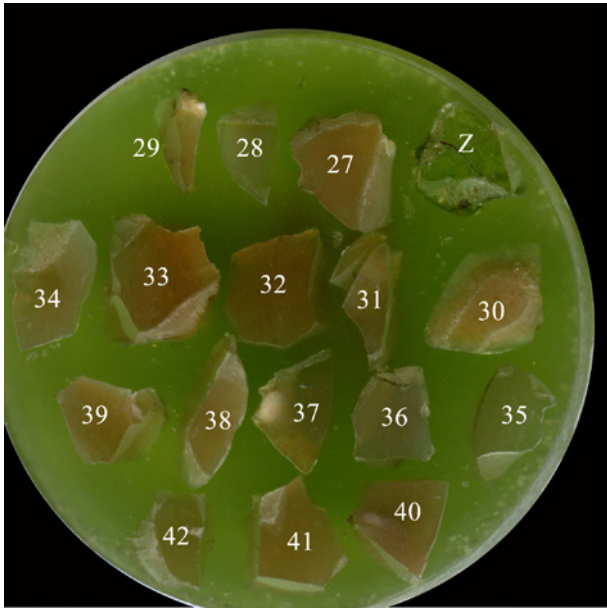
Mount MB 11
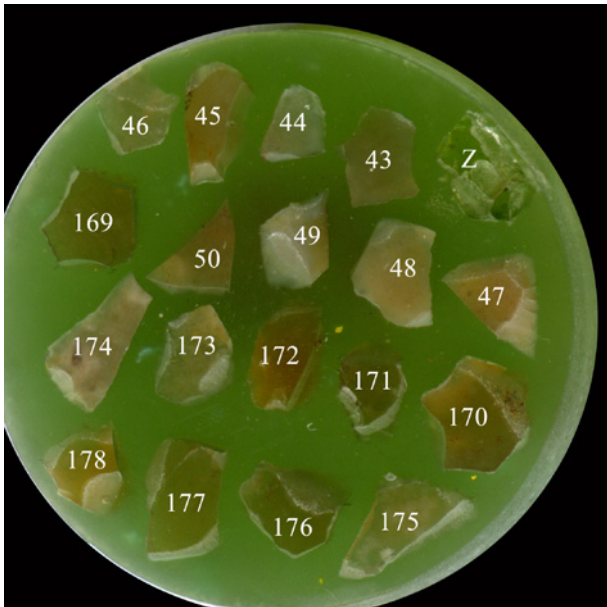
Mount MB 12
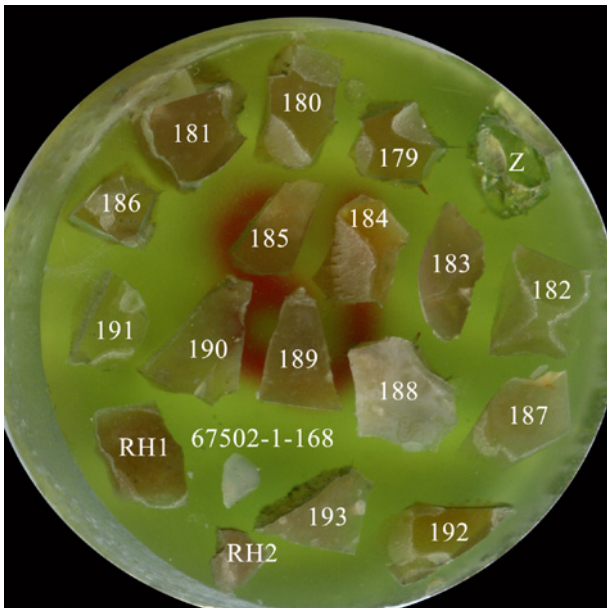
Mount MB 13
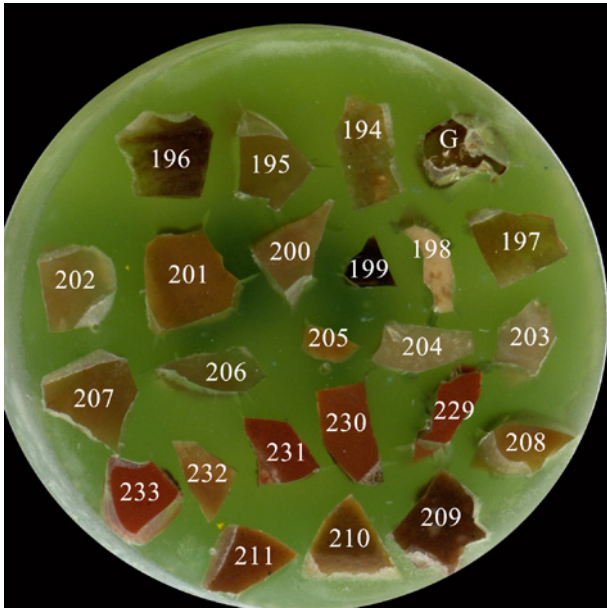
Mount MB 14
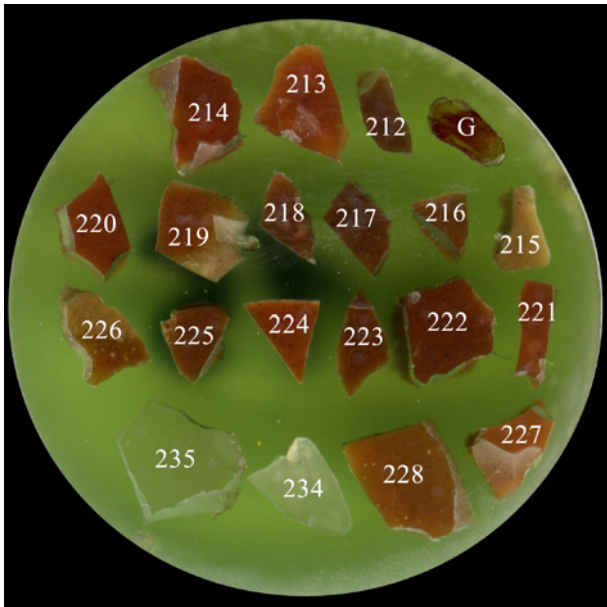
Mount MB 15
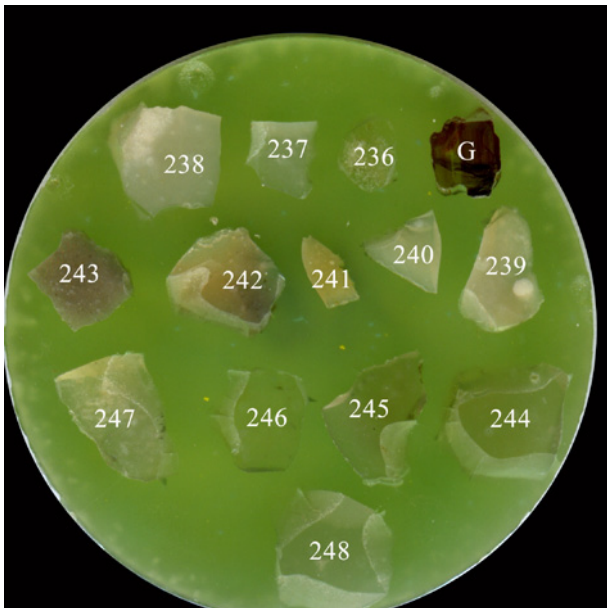
Mount MB 16

Appendix D4: Sample inventory

1. Raw material samples

Sample No.	Source	Mount	Sample No.	Source	Mount
R01			B01		
R255			B02		
R256			B03		
R257			B04		
R258			B05		
R259			B06_1		
R260			B06_2		
R261w			B07		
R261			B08		
R262			B09		
R263			B10		
R264			B11		
R265	Rein-Eisbach	R	B12	Baiersdorf	B
R266			B13		
R267			B14_1		
R268			B14_2		
R269			B15		
RII			B16		
RIV			B17		
RMB01			B18		
RMB02			B19		
RMB03			B20		
ROE01					
ROE02					
ROE03					
RWP02					

Sample No.	Source	Mount
1	Wien Mauer	Mount 5
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
31	Feuersteinmähder	Mount WP2
32		
33		
34		
35		
36		
37		
38		
39		
40		
41	Rein excavation 2010	
42		
43		
44		
45		
46		
47		
48		
49		
50		

Sample No.	Source	Mount
1	Mt. Baldo, Pra da Stua	Mount MJ
2	Mt. Baldo, MB 6	
3		
4		
5		
6	Mti. Lessini ML 3	
7		
8	Mt. Baldo MB 3	
9		
10	Mti. Lessini ML 2	
11	Mt. Baldo MB 1	
12		
13		
14		
15		
16		
17		
18		
19		
20		
21	Mit. Lessini ML 7	
22		
23		
24	Mit. Lessini ML 2	
25		
26	Grubalacke	
27		
28		
29		
30		
31		
32		

Sample No.	Source	Mount
1	Falsztynski Potok	Mount WP1
2		
3		
4		
5		
6		
7		
8		
9		
10		
11	Vlára-Bolešov	
12		
13		
14		
15		
16		
17		
18		
19		
20		
21	Wien Gemeindeberg	
22		
23		
24		
25		
26		
27		
28		
29		
30		

Sample No.	Source	Mount
1	Meusnes-Le Quartier (Dept. Cher-et-Loire) shaft backfilling	Mount MB 9
2		
3		
4		
5		
6		
7		
8		
9		
10		Mount MB 10
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

Sample No.	Source	Mount	Sample No.	Source	Mount
26	Sąspów	Mount MB 10	51	Bębło	MB 3
27		Mount MB 11	52		
28			53		
29			54		
30			55		
31			56		MB 4
32			57		
33			58		
34			59		
35			60		
36			61		
37			62		
38			63		
39			64		
40			65		
41			66		
42			67		
43		Mount MB 12	68		
44			69		
45			70		MB 5
46			71		
47			72		
48			73		
49			74		
50			75		
76	Czajowice	Mount MB 2	89	Ceredo	Mount MB 1
77			90		
78			91		
79			92		
80			93		
81		Mount MB 3	94		
82			95		
83			96		
84			97		
85			98		
86					
87					
88					

Sample No.	Source	Mount	Sample No.	Source	Mount
99	Nemšová Kamenice	Mount MB 7	129	Rothornjoch	Mount MB 6
100			130		
101			131		
102			132		
103			133		
104			134		
105			135		
106			136		
107			137		
108			138		Mount MB 7
109			139		
110		Mount MB 8	140		
111			141		
112			142		
113			143		
114	Vršatské Podhradie Horna Lysa Bana	Mount MB 8	144	Glasenbachklamm/ Elsbethen	Mount MB 5
115			145		
116			146		
117			147		
118			148		
119			149		
120			150		
121			151		
122			152		
123			153		Mount MB 6
124		Mount MB 9	154		
125			155		
126			156		
127			157		
128			158		

Sample No.	Source	Mount	Sample No.	Source	Mount
159	Sant`Anna d`Alfaedo	Mount MB 2	169	Mników	Mount MB 12
160			170		
161			171		
162			172		
163			173		
164			174		
165			175		
166			176		
167			177		
168			178		
229	Vršatské Podhradie Horna Lysa Bana	Mount MB 14	179		Mount MB 13
230			180		
231			181		
232			182		
233			183		
RH1	Rein-Hörgas (nodular chert)	Mount MB 13	184		
RH2			185		
			186		
			187		
			188		
			189		
			190		
			191		
			192		
			193		

2. Sampled artifacts

Sample No.	Inv.No.	Site	Mount
1	15.327	Repolust Cave	
2	15.349	Repolust Cave	
3	15.353	Repolust Cave	
4	15.355	Repolust Cave	
5	15.362	Repolust Cave	
6	15.365	Repolust Cave	
7	15.408	Repolust Cave	
8	15.410	Repolust Cave	
9	15.411	Repolust Cave	
10	15.416	Repolust Cave	
11	15.450	Repolust Cave	
12	15.476	Repolust Cave	
13	15.500	Repolust Cave	
14	15.677	Repolust Cave	
15	15.679	Repolust Cave	
16	15.820	Repolust Cave	Mount 1
17	15.838	Repolust Cave	
18	15.884	Repolust Cave	
19	15.898a	Repolust Cave	
20	24.723	Repolust Cave	
21	24.840	Repolust Cave	
22	24.841	Repolust Cave	
23	24.841	Repolust Cave	
24	24.842	Repolust Cave	
25	24.843	Repolust Cave	
26	24.844	Repolust Cave	
27	24.845	Repolust Cave	
28	24.846	Repolust Cave	
29	24.847	Repolust Cave	
30	24.848	Repolust Cave	

Sample No.	Inv.No.	Site	Mount
31	24.849	Repolust Cave	
32	24.850	Repolust Cave	
33	24.861	Repolust Cave	
34	24.880	Repolust Cave	
35	24.881	Repolust Cave	
36	24.882	Repolust Cave	
37	24.883	Repolust Cave	
38	24.890	Repolust Cave	
39	24.891	Repolust Cave	
40	24.892	Repolust Cave	
41	24.893	Repolust Cave	
42	24.894	Repolust Cave	
43	24.895	Repolust Cave	
44	24.896	Repolust Cave	
45	24.899	Repolust Cave	
46	24.900	Repolust Cave	Mount 2
47	15.515	Repolust Cave	
48	15.540	Repolust Cave	
49	15.544	Repolust Cave	
50	15.548	Repolust Cave	
51	15.559	Repolust Cave	
52	15.560	Repolust Cave	
51	15.566	Repolust Cave	
52	15.570	Repolust Cave	
53	15.571	Repolust Cave	
54	15.573	Repolust Cave	
55	15.580	Repolust Cave	
56	15.585	Repolust Cave	
57	15.590	Repolust Cave	
58	15.592	Repolust Cave	
59	15.611	Repolust Cave	
60	15.616	Repolust Cave	

Sample No.	Inv.No.	Site	Mount
61	15.618	Repolust Cave	
62	15.651	Repolust Cave	
63	15.652	Repolust Cave	
64	15.656	Repolust Cave	
65	15.657	Repolust Cave	
66	15.672	Repolust Cave	
67	15.679	Repolust Cave	
68	15.684	Repolust Cave	
69	15.838	Repolust Cave	
70	15.905	Repolust Cave	
71	16.055	Repolust Cave	
72	16.080	Repolust Cave	Mount 3
73	16.105	Repolust Cave	
74	24.897	Repolust Cave	
75	24.935	Repolust Cave	
76	24.937	Repolust Cave	
77	24.940	Repolust Cave	
78	18.587	Grötsch	
79	18.588	Grötsch	
80	23.649	Tunnel Cave	
81	23.650	Tunnel Cave	
82	23.654	Tunnel Cave	
83	23.655	Tunnel Cave	

Sample No.	Inv.No.	Site	Mount
84	WP083-1	Kanzelkogel	
85	R840	Raababerg	
86	R246	Raababerg	
87	R848	Raababerg	
88	R934	Raababerg	
89	R350	Raababerg	
90	R689	Raababerg	
91	R786	Raababerg	
92	R164	Raababerg	
93	R784	Raababerg	
94	R843	Raababerg	
95	R344	Raababerg	
96	R844	Raababerg	
97	R847	Raababerg	
98	R382	Raababerg	
99	R358	Raababerg	
100	12.480	Zigeuner Cave	Mount 4
101	12.464	Zigeuner Cave	
102	12.471	Zigeuner Cave	
103	12.965	Zigeuner Cave	
104	12.908	Zigeuner Cave	
105	12.472	Zigeuner Cave	
106	12.405	Zigeuner Cave	
107	12.424	Zigeuner Cave	
108	12.438	Zigeuner Cave	
109	12.416	Zigeuner Cave	
110	12.925	Zigeuner Cave	
111	12.465	Zigeuner Cave	
112	12.989	Zigeuner Cave	
113	12.485	Zigeuner Cave	
114	12.488	Zigeuner Cave	
115	12.486	Zigeuner Cave	
116	103.135	Weitendorf	

Sample No.	Inv.No.	Site	Mount
1	558	Weitendorf / Koralmbahn	
2	619	Weitendorf / Koralmbahn	
3	654	Weitendorf / Koralmbahn	
4	577	Weitendorf / Koralmbahn	
5	646	Weitendorf / Koralmbahn	
6	61	Glaserkogel	
7	193	Glaserkogel	
8	229	Glaserkogel	
9	324	Glaserkogel	
10	S 13	Dietenberg	
11	S 15	Dietenberg	
12	11486	Wildon Buchkogel	
13	11482	Wildon Buchkogel	
14	11480	Wildon Buchkogel	Mount A
15	sample 1	St. Ulrich / Waasen	
16	sample 2	St. Ulrich / Waasen	
17	sample 3	St. Ulrich / Waasen	
18	sample 4	St. Ulrich / Waasen	
19	sample 5	St. Ulrich / Waasen	
20	o.Nr.	Zeiring	
21	328	Stainz / Lethkogel	
22	o.Nr.	Aussee	
23	NOI II 2025	Noiberg	
24	NOI II Pl	Noiberg	
25	NOI II Pl	Noiberg	
26	Ri 13320	Noiberg	
27	NOI I Ri	Noiberg	

Sample No.	Inv.No.	Site	Mount
28	NOI I 133	Noiberg	Mount A
29	NOI I 13114	Noiberg	
30	NOI I 110	Noiberg	
31	T1 44	Tesserriegel	
32	T1 70	Tesserriegel	
33	T3 23	Tesserriegel	
34	T3 13	Tesserriegel	
35	T3 21	Tesserriegel	
36	T3 1	Tesserriegel	
37	T2 60	Tesserriegel	
38	T2 67	Tesserriegel	
39	26	Betenmacherkogel	
40	11	Betenmacherkogel	
41	21_1	Betenmacherkogel	
42	10	Betenmacherkogel	
43	11_2	Betenmacherkogel	
44	31	Betenmacherkogel	
45	11A (174)	Betenmacherkogel	
46	GS 1.7	Gnas / Sandriegel	
47	GS 1.4	Gnas / Sandriegel	
48	sample 48	Oberandritz	Mount B
49	OA II Si 6	Oberandritz	
50	OA I Si 46	Oberandritz	
51	OA I Si 56	Oberandritz	
52	OA I Si 48	Oberandritz	
53	OA I Si 113	Oberandritz	
54	OA IIIb Si 1	Oberandritz	
55	OA H 1 Si 3	Oberandritz	

Sample No.	Inv.No.	Site	Mount
N	WA 7724	Krems-Wachtberg	MB 9
O	WA 7770	Krems-Wachtberg	
P	WA 7782	Krems-Wachtberg	
Q	WA 8183	Krems-Wachtberg	
R	WA 8640_31	Krems-Wachtberg	
S	WA 15354	Krems-Wachtberg	
T	WA 17913	Krems-Wachtberg	
U	WA 68497	Krems-Wachtberg	
V	WA 74327	Krems-Wachtberg	
W	WA 87982_46	Krems-Wachtberg	
234	gunflint	Schloß Neugebäude	MB 15
235	gunflint	Schloß Neugebäude	
236	gunflint	Schloß Neugebäude	MB 16
237	gunflint	Schloß Neugebäude	
238	gunflint	Schloß Neugebäude	
239	gunflint	Schloß Neugebäude	
240	gunflint	Schloß Neugebäude	
241	gunflint	Schloß Neugebäude	
242	gunflint	Schloß Neugebäude	
243	gunflint	Schloß Neugebäude	
244	gunflint	Schloß Neugebäude	
245	gunflint	Schloß Neugebäude	
246	gunflint	Schloß Neugebäude	
247	gunflint	Schloß Neugebäude	
248	gunflint	Schloß Neugebäude	

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Key: Anon. = Anonymous author

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10. List of Figures and Tables

Tables

11. List of abbreviations

Terms used throughout the dissertation:

abbreviation	full name
MLAS 1	Multi Layered Approach Step 1 macroscopical analysis
MLAS 2	Multi Layered Approach Step 2 microscopical analysis
MLAS 3	Multi Layered Approach Step 3 geochemical analysis
CCD	carbonate compensation depth
HFSE	High Field Strength Elements
NCA	Northern Calcareous Alps
PKB	Pieniny Klippen Belt
RSS	relevant stratigraphic sequence(s)

Sampled sites:

short code	site name
FST	Feuerstein
RH	Rothornjoch
GL	Grubalacke
ELSB	Elsbethen / Glasenbachklamm
WM	Wien Mauer
WG	Wien Gemeindeberg
NEM	Nemšová Kamenice
BOL	Vlára-Bolešov
VRSA	Vršatské Podhradie
FAL	Falsztynski Potok
MEU	Meusnes
BEB	Bębło
MNI	Mników
CZA	Czajowice
SAS	Sąspów
CER	Ceredo
STA	Sant' Anna D'Alfaedo