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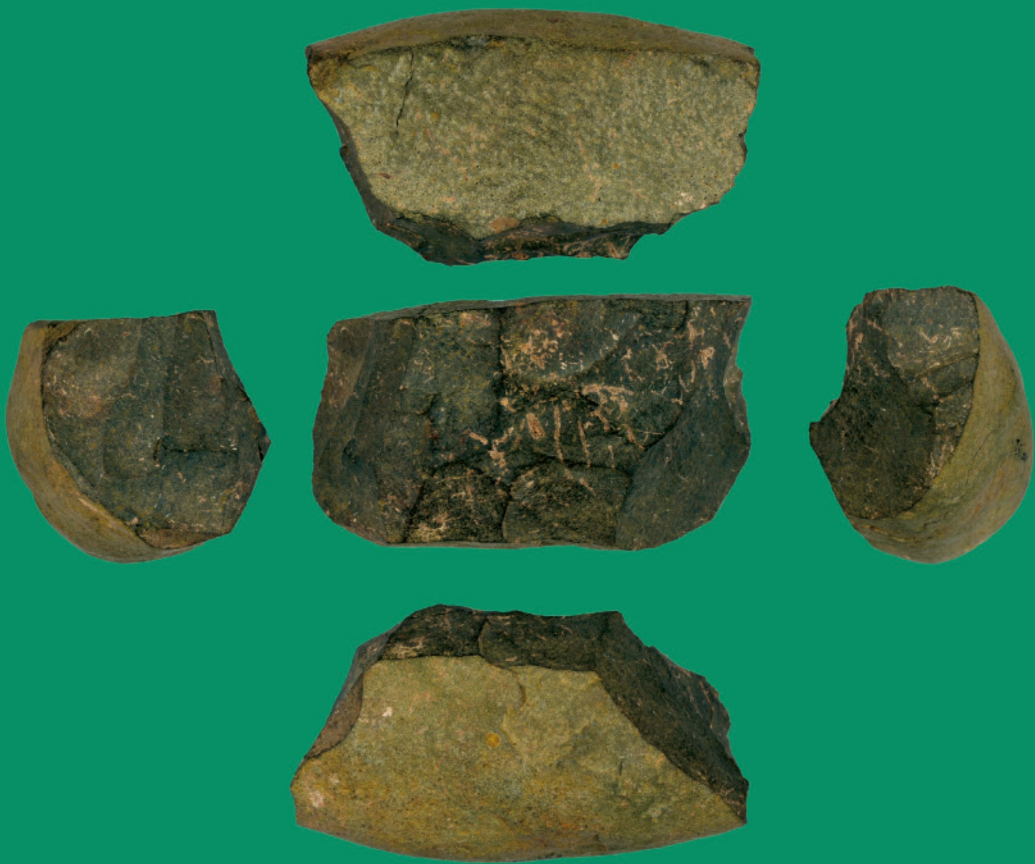

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The Early Holocene Hoabinhian (8300-8000 cal BC) occupation from Hiem Cave, Vietnam

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ABSTRACT

This paper presents a case study from the Hiem cave (Hoà Bình province, North Vietnam) showing how a multidisciplinary approach in archaeological research can develop knowledge on the everyday life of the hunter-gatherer Hoabinhian groups occupying the cave during the early Holocene (8500-8200 cal BC). The archaeological analysis presents the characteristic Hoabinhian artefacts and their usage, while archeozoological, malacological and archaeobotanical research throw light on the way of life, including plant and animal elements of a daily diet as well as the settlement seasonality of the cave.

KEY WORDS
Lithic technology, animal remains, plant remains.

RÉSUMÉ

Une occupation hoabinhienne datée de l'Holocène ancien (8300-8000 avant notre ère) dans la grotte de Hiem, Vietnam.

Cet article montre, à partir d'une étude de cas de la grotte de Hiem (Nord du Vietnam), comment une approche archéologique multi- et interdisciplinaire peut permettre de mieux connaître la vie quotidienne de groupes chasseurs-cueilleurs du Hoabinhien ayant occupé la grotte durant le début de l'Holocène (8500-8200 cal BC). L'analyse archéologique présente les artefacts hoabinhiens classiques et leur utilisation, tandis que les recherches archéozoologiques, malacologiques et archéobotaniques éclairent le mode de vie, ce qui inclut tant les composantes végétales et animales de la diète quotidienne que l'occupation saisonnière de la grotte.

MOTS CLÉS
Technologie lithique, restes animaux, restes végétaux.

INTRODUCTION

Hoabinhian technocomplex

Hoà Bình province in northern Vietnam is considered the homeland of the Hoabinhian cultural phenomenon – this refers mainly to the Muong Vang Valley and the surrounding areas, where the most important Vietnamese Hoabinhian cave sites are located, i.e., Lang Vahn, Hang Muoi, Hoa Binh, Con Moong, Xom Trai (Colani 1927, 1929a, b; Viet *et al.* 1983; Moser 2001; Borel 2012; McAdams *et al.* 2020). Their tool kit belongs to the typical, classical Hoabinhian civilization discovered and described almost a hundred years ago by Madeleine Colani (1927). Her pioneering work remains the point of reference in the research of both numerous caves in the province of northern Vietnam and the whole area where the Hoabinhian cultural phenomenon has been identified (Gorman 1971; Moser 2001; Forestier *et al.* 2015). The article presents the results of archaeological and environmental field work and laboratory analyses of a cave site – Hiem, in the Hoà Bình province, where in 2019 a Vietnamese-Polish team began their research (Fig. 1).

The Hoabinhian is the most representative technocomplex in south-east Asian prehistory for the later hunter-gatherer period. As a mainland technology based exclusively on seasonal tropical environments, this core-tool culture was previously defined in northern Vietnam (Colani 1927, 1929a, b). It is characterised originally by its large, flat and long, largely unifacial cobble tools associated with tropical forest fauna - a technocomplex that persisted in a tropical environment for about 30 000 years. A great majority of Hoabinhian sites in south-east Asia, corresponding with large-scale modern human settlement, are dated to the Last Glacial Maximum (*c.* 20 000 BP) until the Late Pleistocene/Early Holocene transition (Moser 2001; Rabett *et al.* 2009; Bacon 2012; Higham 2013, 2014; Forestier *et al.* 2015). It lasted until the transition to the Neolithic (around 6th millennium BC), when evidence of plant domestication or "proto-agriculture" appears (Gorman 1969, 1970, 1971; Glover 1977). The oldest Hoabinhian site in Asia is the Xiaodong rockshelter, Yunnan Province, southwest China dated to *c.* 43.5 ka BP (Ji *et al.* 2016). The earliest Hoabinhian evidence in Vietnam comes from the Tham Khoung Cave, Lai Chau Province where 14C and ESR dates go back to 33 ka BP (Khol & Quitta 1978; Viet 2004; Borel 2012) while in the Hoa Binh Province the earliest date points to 19.5 ka BP from Hang Cho Cave (Yi *et al.* 2008) and from the area of the Muong Vang Valley the earliest dates range from 18.5 to 16 ka BP (Viet 2004).

Hiem Cave

The site of the Hiem Cave (Xã Bình Hẻm commune, Lạc Sơn district, Hoà Bình Province), referred to as "black soil" in Vietnamese, owes its name to the dark, organic rich sediment filling the cave, used by local farmers as fertiliser. The cave is situated on a limestone hill (20°28'21N, 105°34'22E at the altitude of *c.* 250-270 m a.s.l.), at the level of *c.* 170 m, across calcareous formations covered by wet monsoon forest. The cave's location on the top of a steep slope of a ravine makes it an exceptionally inaccessible area, requiring over an hour's climb from the bottom of the valley. Before preliminary exploration in 2019 the cave was used by the local population. The entrance on the northern side is obstructed by a rock, leaving only a narrow passage, 2-3 m wide, which, however, does not block the sunrays (Figs 2, 3). The cave is 12 m high. Its interior occupies the surface of *c.* 150 m^2, where numerous shells, bones, individual stone artefacts and big querns were found. The central part of the cave displayed evidence of modern damage.

In geological terms, the Hiem Cave is situated in a Permian-Triassic sequence constituting the edge of the continental rift Song Da. The rift zone Song Da is one of the important tectonic units squeezed between large tectonic blocks: the South

FIG. 1. — Site location plotted on the map of northern Vietnam.

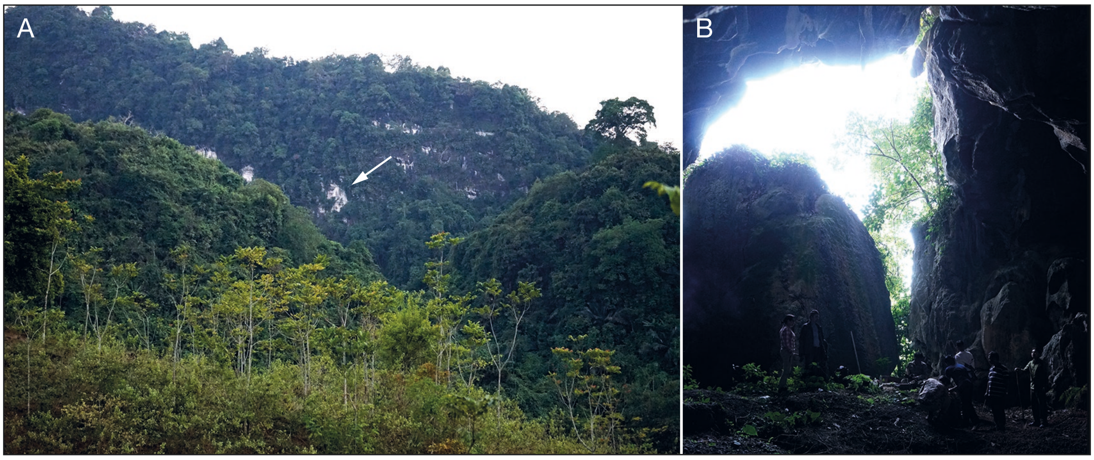

FIG. 2. — **A**, Mountain massif where the Hiem Cave is situated (the **arrow** indicates its approximate location); **B**, view from the inside the cave of the narrow, *c*. 2 m wide passage and the rock blocking the remaining part of the entrance.

China block and the Indochina block (Takemoto *et al.* 2005). In the Hoà Bình Province the formation reaches the thickness of *c.* 5000 m. The formation begins with Permian paralic sediments, from which time basalt outcrops originate (Tran *et al.* 2016). The Permian sediments are covered by the lower Triassic sandstones and siltstones. The younger sequence of the Triassic is composed of conglomerates, sandstones and limestones. The deposits are overlain by the 1000 m thick complex of grey limestones, where the Hiem Cave had developed (Fontaine & Mainguy 1981).

Hiem Cave is one of the newest discovered sites representing the Hoabinhian technocomplex. The cave's inaccessibility contributed to the preservation of various categories of artefacts with significant scientific potential. The aim of our article is an attempt at an interdisciplinary presentation of the adaptation strategies of early Holocene communities associated with the Hoabinhian technocomplex. Our preliminary hypothesis assumes the durability and stability of the strategy of adaptation to the environment adopted by the Hoabinhian community.

Due to the seasonality and chronological complexity of the presence of human groups in Hiem Cave we identified, our research results provide valuable insight into the dynamics of cognitive adaptation and environmental exploitation by hunter-gatherers in the Early Holocene. We hope that the results of our research will provide a new and important voice in the discussion of early Holocene hunter-gatherer behaviour, and the sustainability of their models of adaptation to the rainforest environment of Southeast Asia.

MATERIAL AND METHODS

The inaccessibility of the cave determined the research methods. The area of 2 m^2 was explored. All the material recovered from the deposits on the bottom of the cave was sifted on the spot (with the sieves of the mesh diameter of 0.5 cm) to select paleoecological sources for further analyses. Flotation was carried out for the part of the deposit (*c.* 10%) in the place offering appropriate conditions. Excavated artefacts were recorded within 10 cm levels.

The acquired archaeological and ecological sources were subject to various comprehensive analyses. A Microsoft Access database considering the techno-typological specificity of the technocomplex under study was designed to record the entire lithic inventory. Technological analysis of artefacts was conducted based on "chaîne opératoire" approach which focuses on identifying human activity connected with specific stage of reduction sequences – from raw material acquisition to discard of lithics (Inizian *et al.* 1999; Boëda 2013). This methodological approach has been widely applied in studies of lithic assemblages from Mainland Southeast Asia (MESA) (Forestier *et al.* 2021a, b). All artefacts larger than 10 mm were measured, weighed and classified typologically and technologically (those smaller than or equal to 10 mm were defined as chips and only classified by raw material). Number and direction of flaking scars were analysed for all artefacts; remaining cortex on dorsal side of flakes was measured. In addition, physical state, completeness, heat treatment were recorded for all type of lithics. Refitting studies of lithic artefacts has not been conducted yet.

For use-wear analysis the artefacts were cleaned in an ultrasonic bath for 2-5 minutes. An integrated approach combining observations in low and high magnifications was employed. The former, obtained with the use of an Olympus SZX9 stereoscopic microscope, were especially useful for detecting used edges and assessing the degree of chipping. Images of these were recorded with a Dino lite microscope and stacked in Helicon Focus. Nikon Eclipse LV 100, with magnifications between 200× and 500×, was used for observing and documenting micro-traces. Wear traces formed differently on the matrix and particular crystals. Depending on the magnification, various features could be detected (Asryan *et al.* 2014; Stemp *et al.* 2015). Those included changes of tool morphology, breakage, and chipping. In higher magnifications micro-polish, alterations of grain surface, as well as striations and grooves could be observed. Due to the limited literature dealing with use-wear on chipped basalt artefacts, descriptions of the observed traces were based on the ones proposed for ground tools (Adams 2014; Dubreuil *et al.* 2015).

Geological samples were collected from stratigraphic units. Sedimentological data were collected, following facies analysis and included observations such as the thickness of series, dominant colour, cementation, presence of carbonate, bedding, structures and artefact content. A petrographic analysis was conducted for two raw materials present in the lithic inventory. In order to determine the lithology of selected samples two thin sections for transmitting light were prepared for representative rocks. The observations were carried out with a standard petrographic microscope. The archaeometric examination of samples of mineral substances from the Hiem Cave were carried out with a scanning electron microscope (Veselinovic *et al.* 2021), infrared spectrometer and X-ray diffractometer (Lebon *et al.* 2019).

The osteological material was analysed with the use of the standard procedure of archaeozoological assessment of fauna material (Reitz & Wing 2008). It comprised taxonomic and anatomical identification of the remains. The osteological material was also examined to identify gender, age, osteometric data and possible taphonomic traces, including bone processing.

The archaeobotanical and malacological material was hand-selected during the sifting of the sediment from individual levels of the archaeological trench. Further processing was carried out in laboratories. Plant material, pre-separated from the sediment matrix, was described and washed on two sieves with a mesh diameter of 0.5 and 0.2 mm. The initial wet segregation revealed a lack of delicate parts of the diasporas, the material was then dried and re-examined with a stereoscopic microscope.

Mollusc shells were gently cleaned with a soft brush to remove any adhering sediment. All the identifiable shells and shell fragments were classified taxonomically, to the species level if possible. The classification was based on the keys and atlases (Köhler & Glaubrecht 2006; Nantarat *et al.* 2014; Raheem *et al.* 2017; Do *et al.* 2018; Do & Do 2019) and online datasets, e.g. Global Biodiversity Information Facility (GBIF), the MUSSEL Project Website (MUSSELp).

Radiocarbon dating (AMS) of the burned nutshells was conducted by Beta Analytics Testing Laboratory, Miami, Florida. Radiocarbon Ages have been corrected for total fractionation effects and calibration was performed using 2013 calibration databases.

RESULTS

Chronology

Radiocarbon chronology of the three stratigraphic horizons in the Hiem Cave determined human activity for the early Holocene within the narrow brackets of three centuries between 8500 and 8200 cal BC (Table 1).

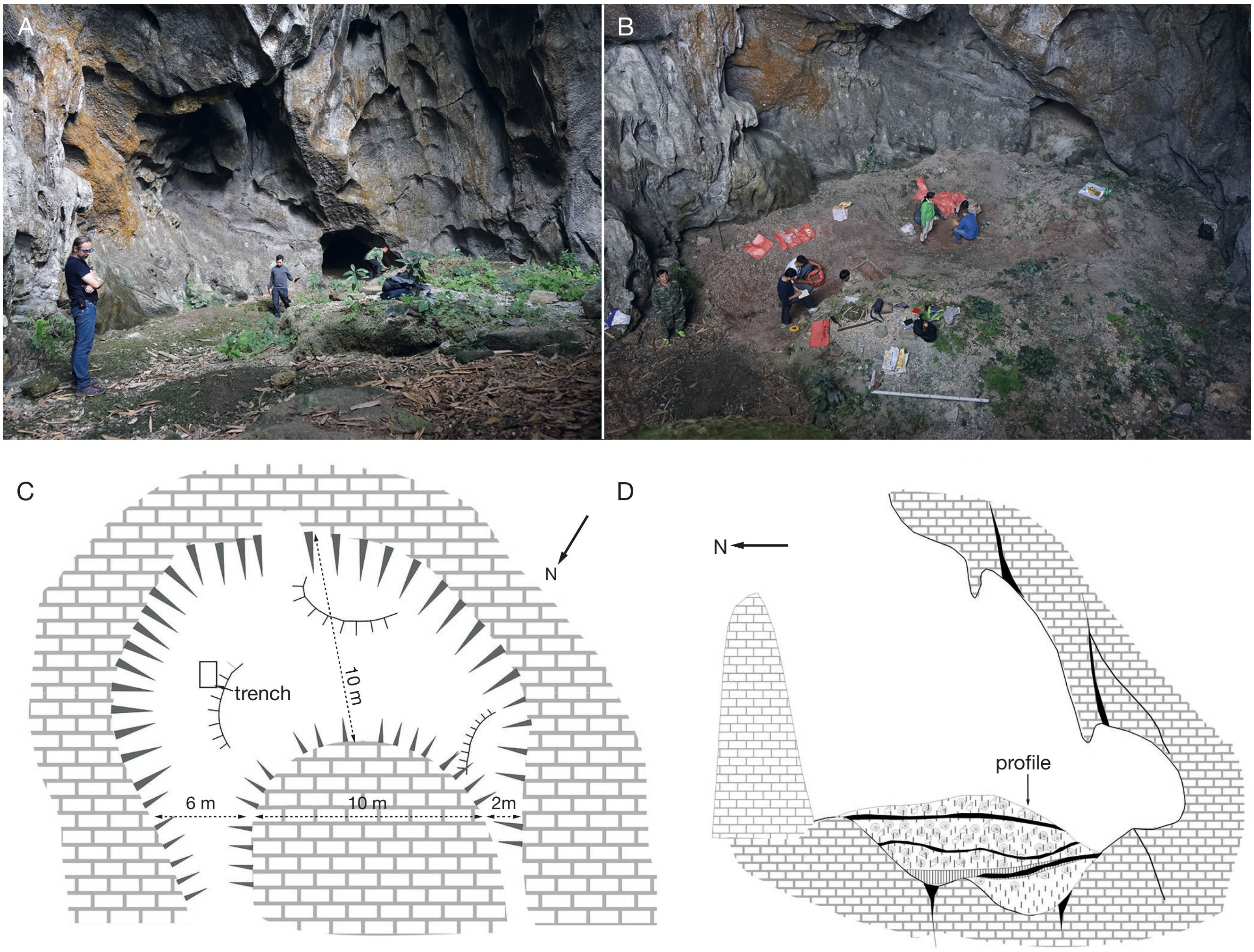

Fig. 3. — Hiem Cave: **A**, **B**, interior of the cave; **C**, plan of the cave; **D**, cross-section of the cave.

Sedimentary stratigraphy

A sediment sequence more than 2 m thick was exposed. The succession consists of three main series of deposits comprising seven to eight discontinuous layers (Fig. 3D). The layers differ in colour, grain-size composition, the number of shells and artefacts, content of organic matter and carbonates. The lowest series I consist of rusty, clayey weathered limestone with single snail shells. Series II, laying on the series I consist of six layers which reflect considerable influence of the geological processes outside the cave such as chemical and physical weathering processes that acted with different intensities. The whole section of series II is 1 m thick and it is composed of grey-brown red clay with numerous snail shells. Distinguished layers are 5-10 cm thick and consist of dark brown organic layer or grey clay lenses of kaolinite (Fig. 4). Kaolinite sediments at a depth of 1.0 m; 1.15-1.20 m and 1.3 m have visible lamination due to subtle changes in the grain size which indicate deposition in the very low energy conditions.

The most distinctive layer at 0.7-0.8 m depth containing stone artefacts, bones and nutshell, constitutes culture horizon and was dated to 8279-8180 cal BC. Similar layers (or lenses) are located at a depth of 1.0-1.1 m; 1.2 m; 1.3-1.4 m. The sediment sequence finishes with a rather continuous thick black organic layer, referred to as "black soil" records the process of soil formation. Series I is composed of mixed bulk sediment originated in modern times, probably during the exploration for an organic layer.

Table 1. — Radiocarbon (AMS) dating results for the settlement from Hiem Cave, Hoa Binh Province. Beta – Beta Analytics Testing Laboratory, Miami, United States of America. Abbreviations: **lab.**, laboratory; **prob.**, probability.

Depth (cm)	Material dated	Lab. code & sample no.	Conventional age (sample BP)	Calibrated age (cal BC) 95.4% prob.
70-80	nutshell	Beta – 554963	8970 ± 30	8279-8180
100-110	nutshell	Beta – 554964	9240 ± 30	8560-8332
130-140	nutshell	Beta – 554965	9140 ± 30	8356-8281

Rock minerals

Lumps of minerals, white and red in colour, were found in all explored horizons. The examination showed that they were kaolinite and hematite, respectively.

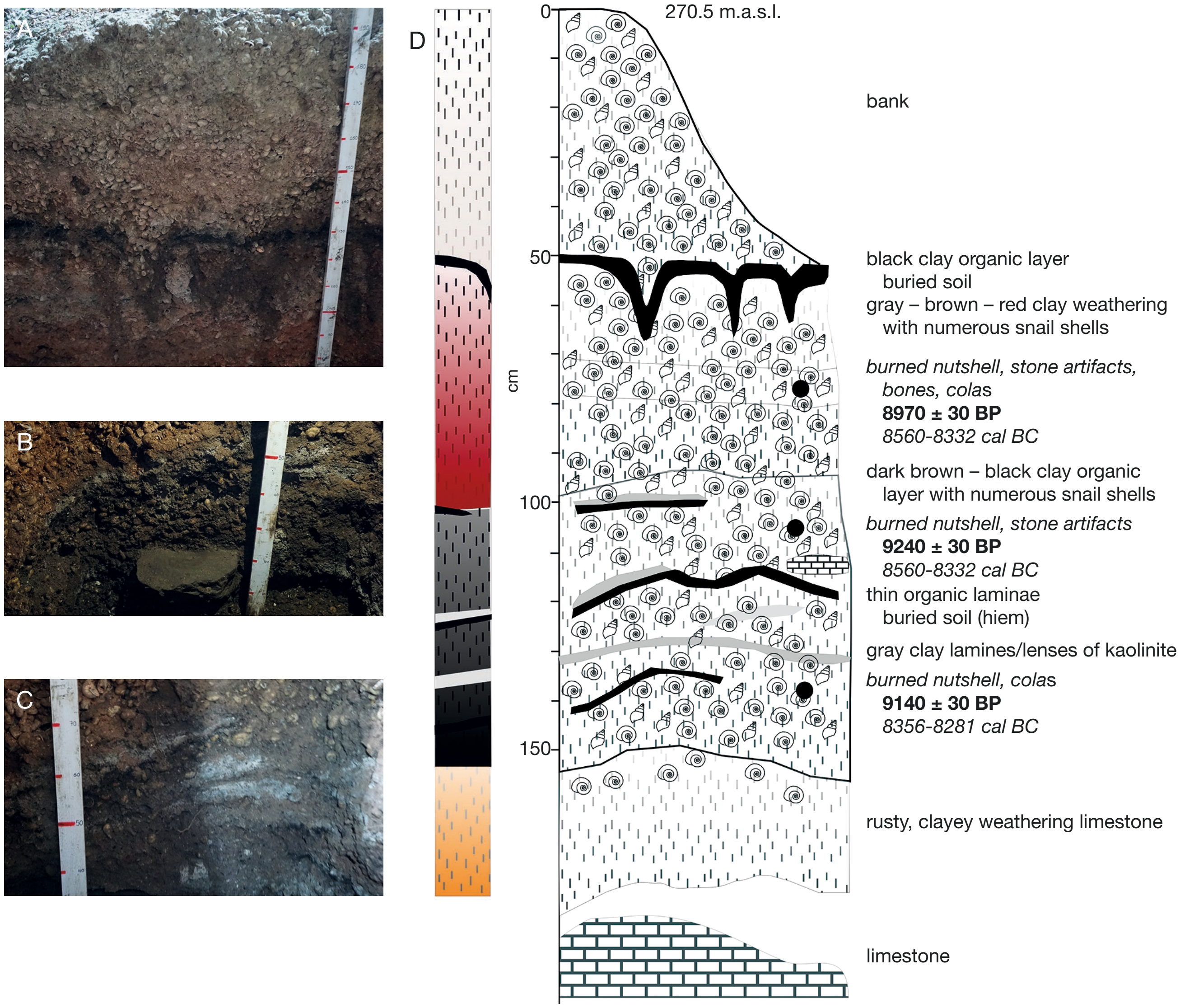

Fig. 4. — Hiem Cave stratigraphy: **A**, black clay organic layer; **B**, burned nutshel and limestone quern; **C**, boundary between gray clay and weathering limestone; *italics*, radiocarbon determination; **bold**, calibrated date. Profile location: see Fig. 3D.

The sample of mineral substances retrieved from the surface of the quern yielded strong analytic signals of oxygen, calcium and carbon, which after molecular examination were preliminarily interpreted as calcium carbonate. Infrared spectroscopy and XRD confirmed that the main component of the quern residue is calcite containing iron, aluminium, potassium, magnesium and sodium present in the amounts never exceeding 1% in weight (Fig. 5A). The set of three samples included two lumps of very similar, bright pinkish-red colour and one a bit more rust-coloured. The examination revealed that the latter was a mixture of minerals: mainly quartz, muscovite and hematite. Presence of Fe_2O_3 was identified in infrared spectroscopy (FT-IR), detecting the oscillation of the Fe-O bond within the range of 450-580 cm^{-1}, and confirmed by matching to the reference spectrum of hematite from the HR Inorganic spectra library. The obtained results were confirmed by the XRD analysis, indicating that the specimen's main component is quartz accompanied by hematite and muscovite (Fig. 5B). In the next two samples the main component is silicon monoxide accompanied by great amounts of aluminium and iron compounds. The FT-IR particle analyses showed that the samples may be classified as ball clay. The XRD analysis proved that the samples also contain muscovite and quartz (Fig. 5C, D).

Lithic assemblage

Two types of lithic raw material were found to have been used in the assemblage from Hiem. The first is magmatic (volcanic) rock of dark-grey to black colour, compact and massive, belonging to upper-Permian, highly-Ti (titanium) Hoa Bihn basalts. Its main component is small crystals of plagioclases and pyroxenes accompanied by olivines. The microcrystals have a similar composition. The crystals are considerably corroded. The secondary component detected in the rock is

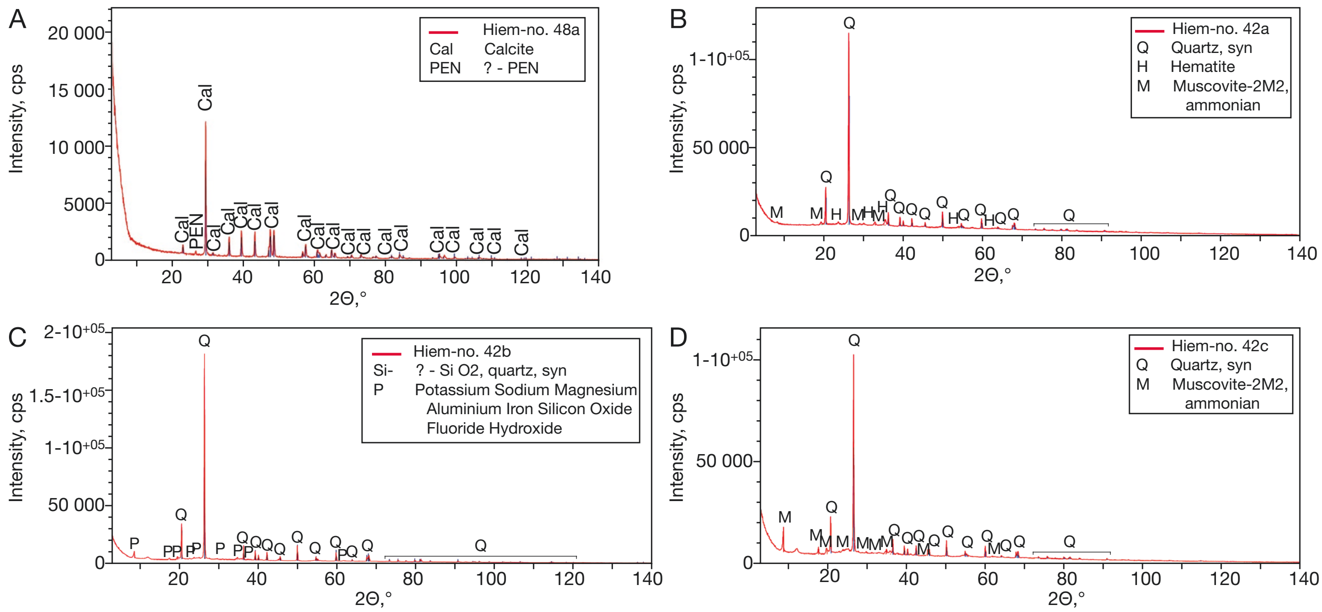

FIG. 5. — Diffractogram of the analysed samples with proposed phase identification: **A**, mineral substance from the surface of the quern (from Fig. 13); **B**, sample of bright pinkish-red colour; **C**, **D**, sample of white colour.

chalcedony, probably of hydrothermal origin. The other raw material is dark-grey massive limestone. Its main component is fine-crystalline calcite – micrite.

Altogether 268 lithic artefacts were found. Two artefacts were collected from the surface of the site area: one sumatralith (Fig. 6A) and one chopper (Fig. 6B), both made from basaltic flat cobbles. The sumatralith is preserved in a complete form with circular blow scars visible on the second face. This surface is completely decorticated and only individual negatives are visible on the planar face. Chopper was made from a flat block; distal and lateral cutting edges were created with single unidirectional invasive blows. Small flaking scars from the edge shaping are visible on the lateral edge.

The trench covered the area of 2 m^2 and reached the depth of 140 cm. Altogether 157 artefacts in Square meter A (Sqm A) and 104 lithics in Sqm B were found during the exploration (Fig. 7). The total weight of all buried (n = 261) artefacts is *c.* 11.4 kg. The first group of lithics discovered during the exploration of the sediments is cobble tools recognized as the fossile directeur of the Hoabinhian culture: four sumatraliths and three choppers. Two choppers were made from basalt cobbles and one from limestone block; one is preserved only fragmentarily. The complete forms have from five to six unidirectional flake scars located on the distal edge (limestone) or lateral edge (basalt). Only one sumatralith is preserved in a complete form and three others are preserved fragmentarily. Basaltic cobbles were used as raw material for the production. The tools have plano-convex (n = 2) or trapeze cross sections (n = 2). The reduction and shaping stages were aimed at the unidirectional detachment of the end and one side (n = 2), only the end (n = 1) or both sides (n = 1).

The second group comprises precores and cores. Three complete flake cores were discovered at Sqm A at the following depths: two cores at 30-40 cm and one at 120-130 cm. One of the cores located closer to the ceiling is a unidirectional core made from limestone block. Five flaking scars are visible on the flaking surface – three of them are invasive and two are shorter with hinge fracture; striking platform has no signs of the preparation. The second core, discovered in deeper layers was a basaltic cobble, which was reduced unidirectionally at two first stages of reduction and it bares traces of orientation changed at the last stage of reduction (Figs 8; 9). The change of core reduc-

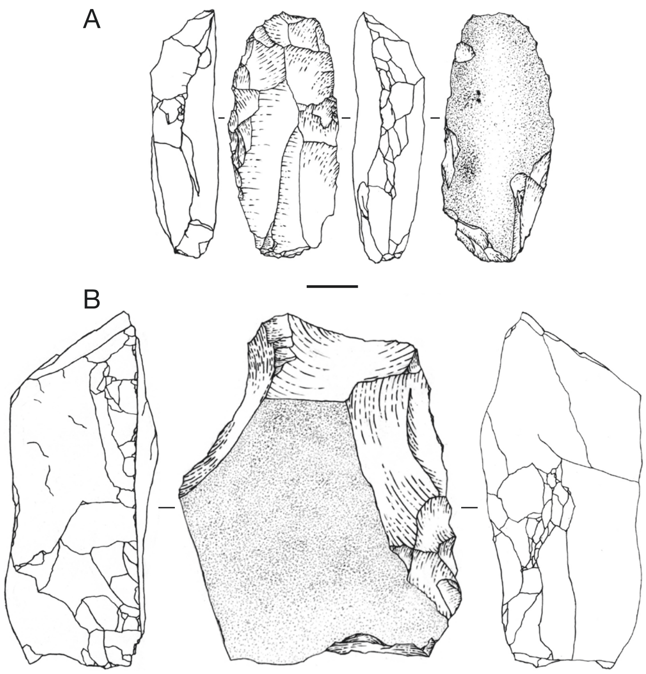

FIG. 6. — Hiem Cave: **A**, sumatralith; **B**, chopper. Scale bar: 3 cm.

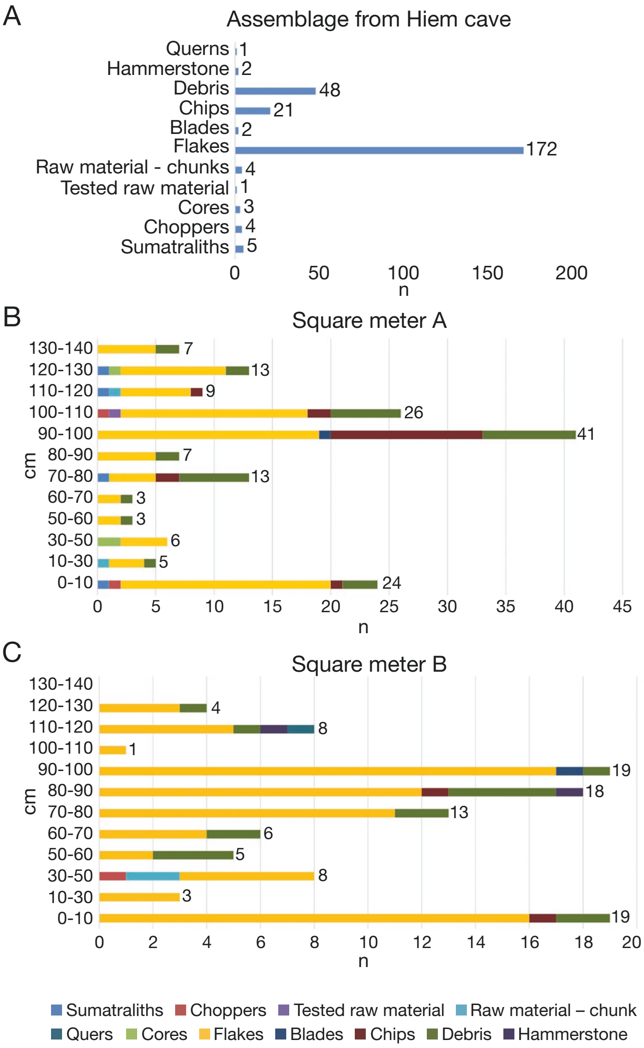

FIG. 7. — Hiem Cave. Lithics assemblage structure: **A**, types and number of artefacts; **B**, location (depth) and number of lithics within Square meter A; **C**, location (depth) and number of lithics within Square meter B. Abbreviation: **n**, number.

FIG. 8. — Hiem Cave. Core with the changed orientation of flaking. Scale bar: 3 cm.

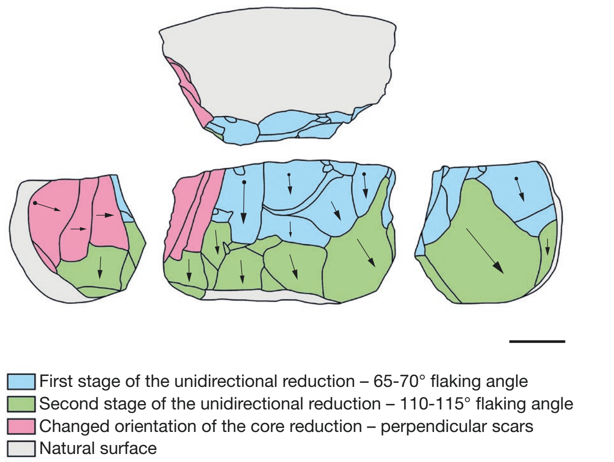

FIG. 9. — Hiem Cave. Flaking sequence of core with changed orientation. **Arrows** represent direction of negatives; **arrows with dot**, presence of bulb negative. Scale bar: 3 cm.

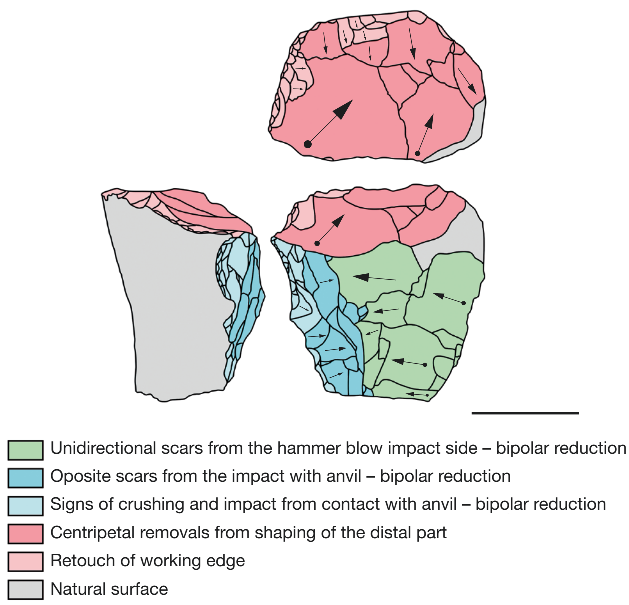

FIG. 10. — Hiem Cave. Flaking and shaping stages of core/shaped tool. **Arrows** represent direction of negatives; **arrows with dot**, presence of bulb negative. Scale bar: 3 cm.

tion strategy was caused due to the intensive reduction of flaking surface and lack of flaking control (flaking angle has changed from 65-70° to 110-115°) at second stage of unidirectional sequence. Technological features indicate using of free-hand percussion. Also in this case, natural surface without preparation was used as a striking platform. The last core represent different reduction sequence and it combines debitage reduction and shaping. First stage is connected with bipolar reduction on anvil (Fig. 10); main flaking unidirectional scars but also traces of impact with anvil in the form of opposite scar and signs of crushing near the edge. Second stage represents shaping of block focused

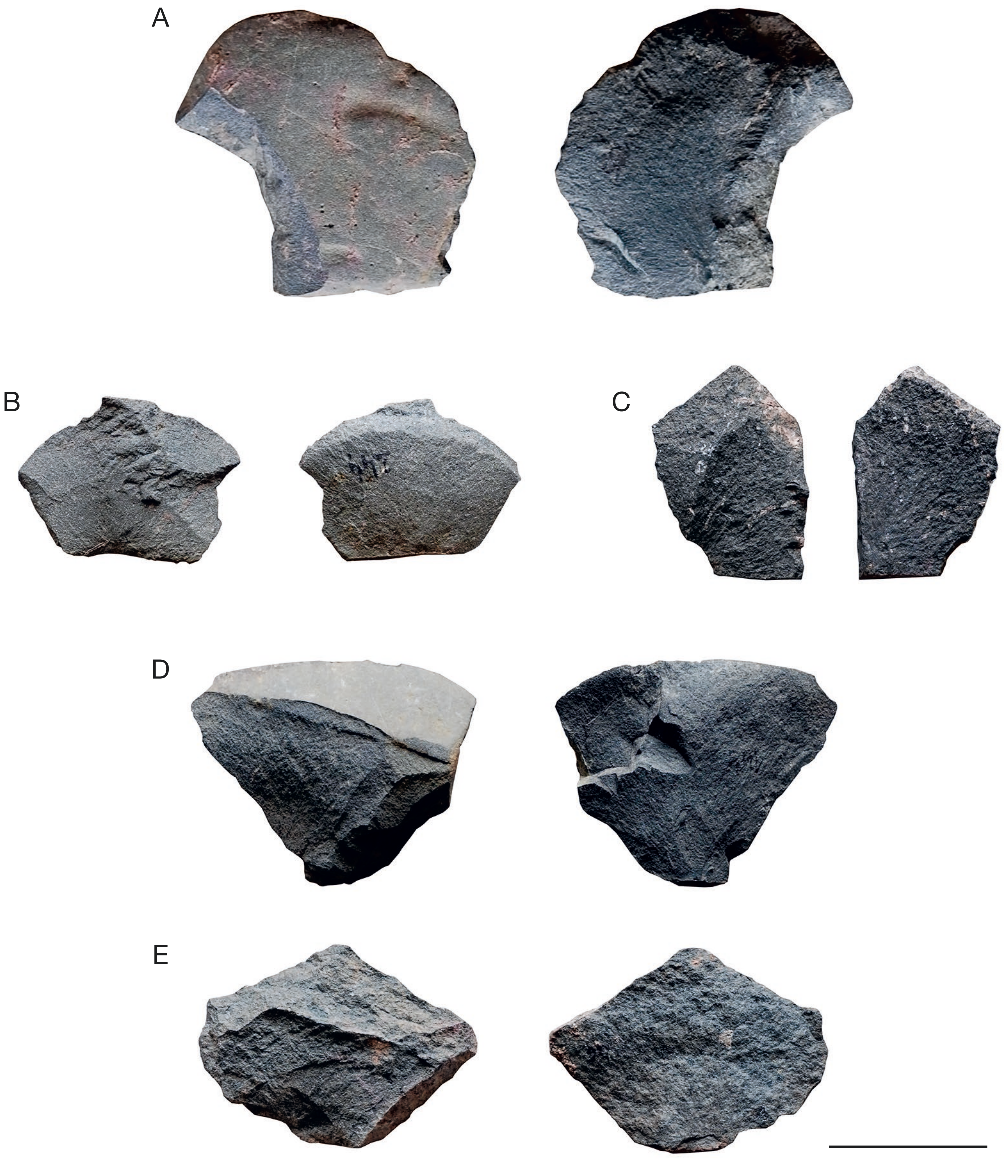

Fig. 11. — Hiem Cave. Selected flakes. Scale bar: 3 cm.

on multidirectional flaking preparation of distal part with working edge retouch. This lithic is a mixed of core and also shaped tool. Besides, one tested basalt cobble with a single negative scar was discovered at the site.

The most numerous group includes debitage/shaping flakes and waste (n = 243) (Fig. 11A-E). Most core/cobble reduction products are flakes (n = 172) made from basalt (n = 169) and limestone (n = 3). One hundred and fifteen flakes are preserved in a complete form, 52 are other fragments and five are fragments broken in half (siret breakage). The flakes are preserved in a very good condition; in the case of 122, the physical state of preservation was determined as fresh and 50 have poorly visible negative scars, on dorsal face. Most of flakes were produced during the advanced stage of reduction (Fig. 12); they have no cortex (n = 78) or have less than 50% of natural surface (n = 57). The others are cortex flakes (n = 13), which have more than 50% of natural surface on dorsal face (n = 9). The predominant number of flakes were detached during unidirectional reduction (n = 110); 18 have perpendicular negatives on dorsal face, 12 are multidirectional ones and others four have opposite scars. Six types of platforms were recognised in the assemblage: cortex (n = 82), plain (n = 23), linear (n = 13), faceted (n = 5), punctiform (n = 3) and dihedral (n = 2). The analysis of flakes dimensions shows a great variety of core reduction products (Table 2). The other types of artefacts included in this group are: two blades (made from basalt), 21 chips (basalt) and 48 debris (basalt = 41; limestone = 6; sandstone = 1).

The next group are other artefacts, which includes: two hammerstones / hand stones and four raw material chunks. Two sandstones in globular shape have traces on the surface visible with the bare eye and characteristic of hammerstones.

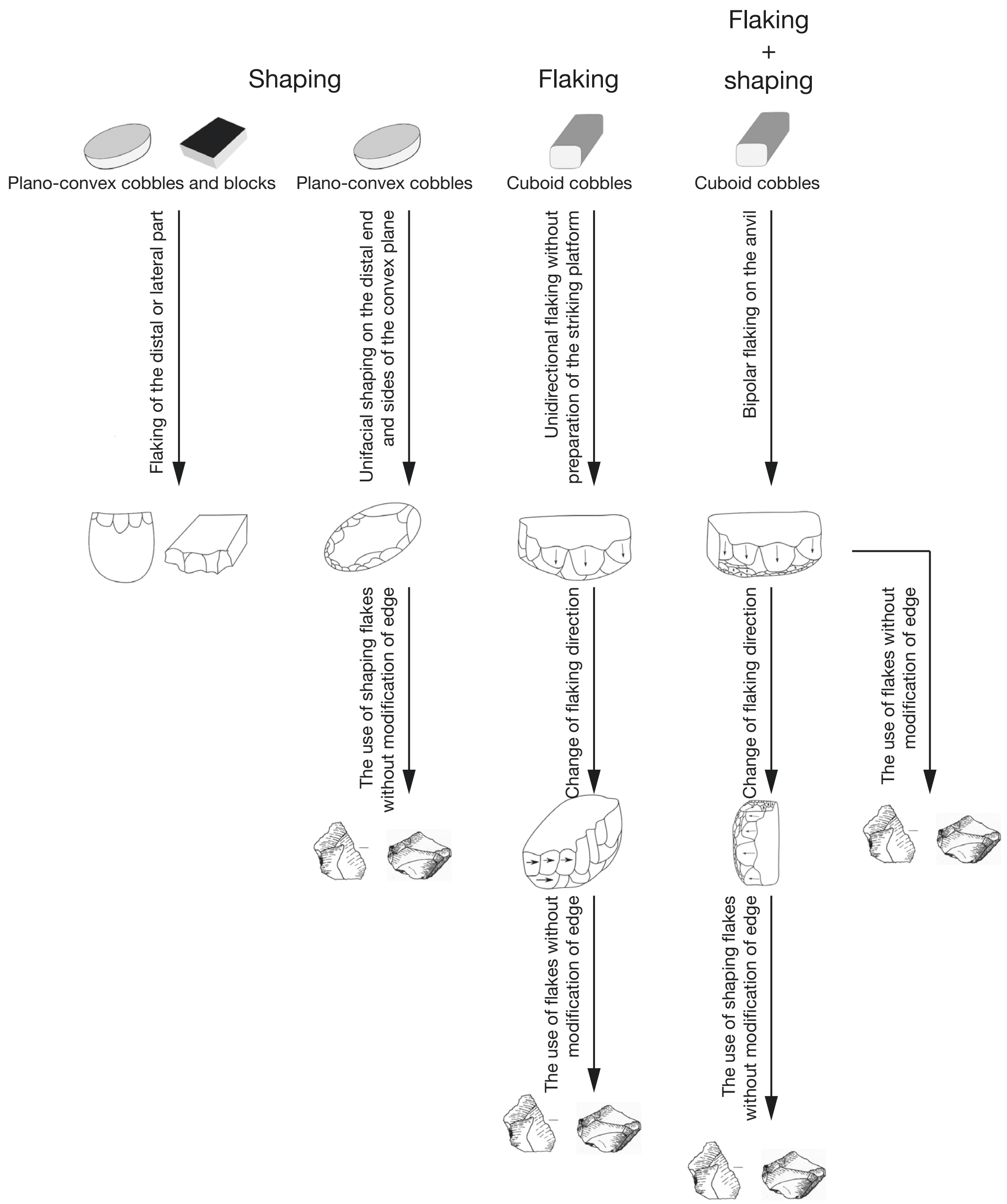

FIG. 12. — Hiem Cave. Examples of production sequence recognized in the lithic assemblage.

TABLE 2. — Dimension of flakes (in mm). Abbreviations: **Max.**, maximum; **Min.**, minimum; **n.**, number; **St.**, standard.

	n.	Min.	Max.	Mean	Median	St. deviation
Max. length	115	10.8	71.6	33.9	31.7	11.77
Max. width	115	12.9	90.2	36.3	34.2	14.88
Max. thickness	115	3	45.2	10.8	9.2	5.96
Weight	115	0.9	254.4	17.6	9.8	29.95

The last artefact discovered at Sqm B at the depth of 110-120 cm is a quern made from limestone (Fig. 13). This artefact has small reddish residue spots visible on the surface and individual negative scars detached during the shaping of a block side.

MICRO-WEAR STUDY

In total, 10 basalt artefacts: nine flakes and a core, were analysed. Use-wear traces were detected on four of them (Fig. 14). Visible chipping of the edges was the first indication of use-wear. The chips varied in shape and size. Smaller ones with feather endings could have been produced by processing softer material, whereas deeper scars with a step or feather ending would be the result of working with harder material.

Two patterns of micro-traces could be distinguished on tool surfaces. In the first, the traces appeared softer and reached deeper into the artefacts' surface (Fig. 14A, E). Grain rounding was noted, together with bright, fluid polish (Fig. 14B, F). Little or no striations were visible on the edges. This type of use-wear could have arisen through processing, most possibly cutting, plant materials.

The traces of the second type were more limited and concentrated mostly on the edges of the tools (Fig. 14C). Numerous, directional striations could be observed on the levelled surfaces of phenocrysts. Alterations concentrated primarily on the elevated parts of the surfaces. Matt and thin micro-polish did not reach the lowest parts of the topography (Fig. 14D). This type of traces could be produced by hard material, such as bone or wood.

The characteristics of the traces observed on four tools suggest that they were used for a rather short time. No traces of use-wear were detected on the remaining artefacts. The edges appeared fresh in both low and high magnitudes. Neither chipping nor micro-polish were observed.

Archaeozoological remains of vertebrate animals

Altogether 224 remains of vertebrate animals (Vertebrata) were discovered during the exploration of the trench. Despite its relatively small size, the collection was quite diversified taxonomically and anatomically. The material was considerably fragmented, which affected the success rate of identification, i.e., the cognitive impact of the fauna material. The NISP (Number of Identified Specimens) was 58.0%. The physical condition of the remains resulted from the influence of taphonomic factors at the biostratonomic and diagenetic stages. The shape of the bone remains proved that the fragmentation was the result of human (consumers') activity. The bones were fragmented, broken and sometimes subject to heat treatment – roasting over fire. As a result of diagenetic processes and, especially water, the animal remains were to a certain extent mineralised. In the case of sites situated in the karst and cave landscapes, the processes and factors affecting organic remains are exceptionally complex (Bacon *et al.* 2008).

The remains of mammals (Mammalia), birds (Aves), reptiles (Reptiles), amphibians (Amphibia) and fish (Pisces) were identified. It was thus very taxonomically diversified material, but predominated by the elements of skeletons of two groups: mammals and reptiles. Mammals constituted a majority – 66.9% NISP and reptiles – 26.1% NISP (Table 3).

The mammal remains were the most diversified in terms of their taxonomy. Bones representing animals from five orders were distinguished: primates (Primates), even-toed ungulates (Artiodactyla), carnivores (Carnivora), bats (Chiroptera), rodents (Rodentiae) (Table 1). The order of even-toed ungulates was the best represented – osteological remains of as many as three families were identified: Bovidae Gray, 1821, Cervidae Goldfuss, 1820 and the most numerous in Hiem: Suidae Gray, 1821. The remains of the wild boar (*Sus scrofa* Linnaeus, 1758) were the predominating component of the osteological material in Hiem, constituting 40.2% of mammal bones and 26.9% NISP.

In terms of frequency of occurrence, the second position is occupied by the remains of tortoises, i.e. reptiles. The remains of two species were identified: Asian forest tortoise (*Manouria emys* (Schlegel & Müller, 1840)) and elongated tortoise (*Indotestuda elongata* (Blyth, 1853)), which constituted 23.0% NISP. The remaining species of animals observed in higher frequencies were muntjac (*Muntiacus* sp.) and rhesus macaque (*Macaca* sp.). The remaining species of mammals (gaur [*Bos frontalis* Lambert, 1804] or banteng [*Bos javanicus* d'Alton, 1823], deer, gibbon, marbled cat [*Pardofelis marmorata* (Martin, 1837)], rodents and bats) were recorded in minimum numbers, similarly as the third species of reptiles: the varan was represented only by a few elements of the skeleton. All rare remains of birds came from the representatives of the order of gallinaceous birds (*Galiformes*). Two remains of an amphibian and a vertebra of a fish were also identified in the assemblage.

Fig. 13. — Hiem Cave: the limestone quern with residue spots visible on the surface and individual negative scars detached during block shaping. Scale bar: 10 cm.

The analysis of the anatomical distribution of the bones of mammals and reptiles revealed an interesting regularity, especially in the case of mammals (Table 3; Fig. 15). The elements of the skeleton of the bos, muntjac, wild boar and monkey were mainly the fragments of bones from the parts of the carcass which are the most attractive for consumption, i.e., bearing most meat. In the whole group of mammal bones only two fragments of a skull and individual fragments of distal parts of legs were recorded. Among the remains of the tortoises a half were elements of the carapace, mainly the plastron. Only one bone of an immature animal was found – it was a bone of a rhesus macaque.

The analysis of the osteological material from Hiem did not yield any evidence of use of tools or processing for consumption. However, there was evidence of heating or charring the bone fragments, which resulted from disposing of them in the fire, thus burning in the temperature of *c.* 1000°C. The damage of this kind was observed on the muntjac's three bones and the wild boar's five bones.

Molluscs

At the Hiem site mollusc shells occur continuously and in significant numbers along the 1.5 m profile of the deposits excavated (Table 4). Mollusc assemblage is composed of terrestrial snails (66 shells), aquatic snails (57 shells) and mussels

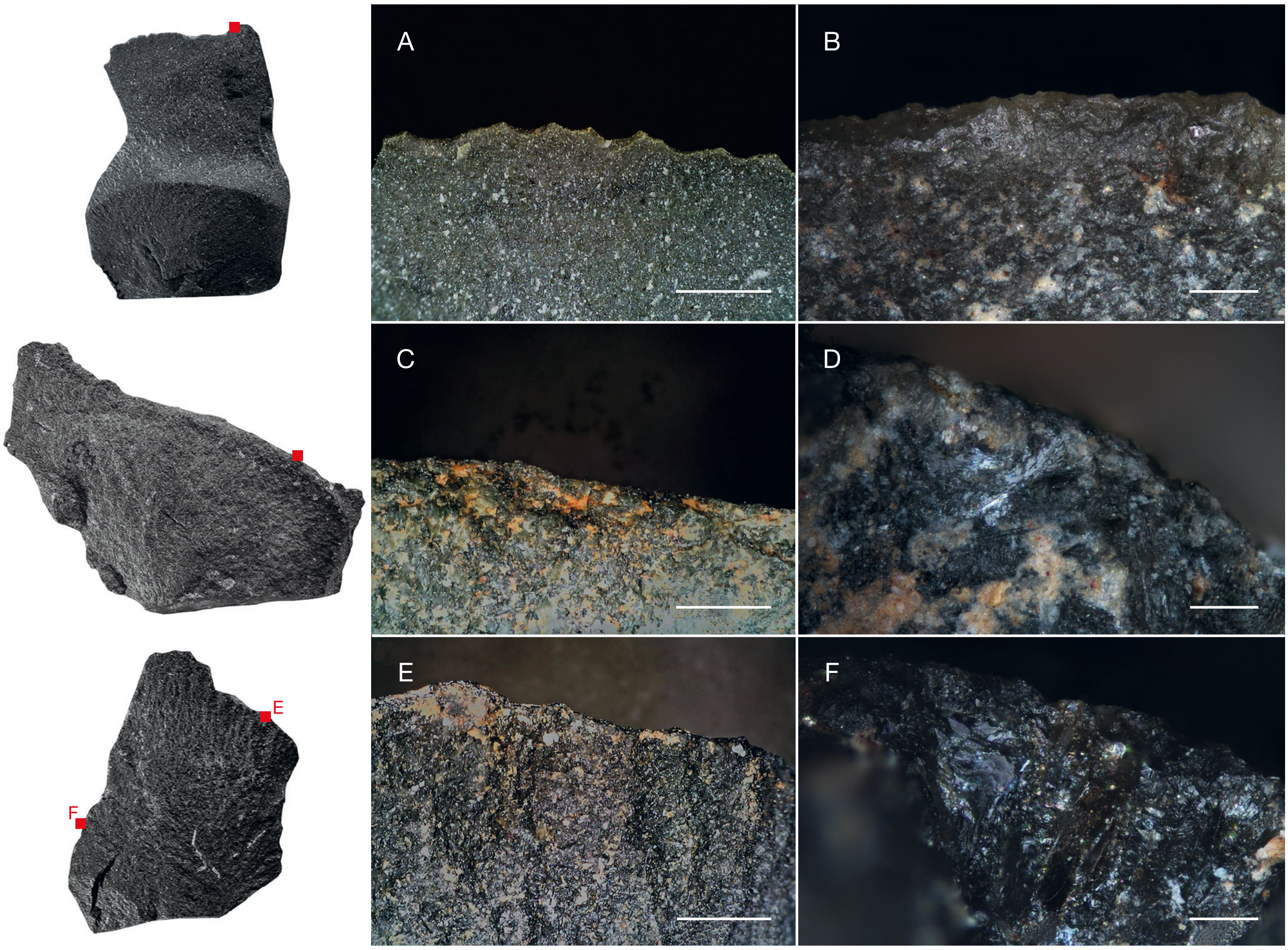

FIG. 14. — Hiem Cave. Micro- and macro-traces observed on the surfaces of the artefacts. Scale bars: A, C, E, 1000 ųm; B, D, F, 100 ųm.

(17 valves) (Table 4). The most numerous land snail, *Cyclophorus* spp., is accompanied by *Camaena vanbuensis* E.A. Smith, 1896, *Camaena* sp., *Garnieria* sp. and *Nienauchenia dautzenbergii* (Morlet, 1893). Among the aquatic snail species are *Brotia* (*Antimelania*) spp. and *Viviparus* spp. The recognisable mussel shells and shell fragments of the Unionida order were classified as *Lanceolaria* spp. and *Nodularia* sp.

The shells classified as *Brotia* spp. have their outer surfaces abraded, which prevented recognition of the external sculpture of the shells and made the detailed taxonomic classification difficult. However, based on the shell material available, two shell morphotypes were distinguished. The first one with the last whorl rounded and deeper suture. The second one with a blunt edge in the lower part of the whorl and shallow suture, possibly *Brotia swinhoei* (H.Adams, 1870).

Archaeobotany – plant remains

Archaeobotanical analysis revealed the presence of nut shells of *Canarium* sp. in each of the excavated levels from the Hiem Cave. It was represented by apexes, bases and fragments of nuts (Table 5; Fig. 15D). All elements bore traces of charring. Unfortunately, lack of diagnostic characteristics does not allow determining the species. In the samples from the level of 90-100 cm, several small and amorphous fragments, which do not come from nut shells, were discovered. It is possible that these are the charred parts of the kernels of *Canarium* sp.

DISCUSSION

Technological behaviours in Hiem Cave

The production methods of flaking tools discovered at site Hiem fits into the broader picture of technological behaviours known from the other Pleistocene and Holocene Hoabinhian sites of south-east Asia (White & Gorman 2004; Forestier *et al.* 2013, 2015, 2021a, b; Ji *et al.* 2016; Marwick 2018; Yinghua *et al.* 2021).

The lithic production was based only on the use of local raw materials: basaltic or limestone cobbles and blocks. Four different production sequences have been identified in assemblage from Hiem Cave (Fig. 12). Core tools were produced mainly with two different methods. First was aimed at the production of choppers made from plano-convex cobbles and blocks, which have shaped a distal or lateral cutting edge with series of few unifacial scars (Zhou *et al.* 2020; Forestier *et al.* 2021a, b). The second type of cobble tools – Sumatraliths – were produced with

TABLE 3. — Taxonomic distribution of animal remains from Hiem Cave.

Order	Family	Genus	Species	Vernacular	Number of remains
Artiodactyla Owen, 1841	Bovidae Gray, 1821	*Bos* Linnaeus, 1758	*Bos frontalis* Lambert, 1804 / *Bos javanicus* d'Alton, 1823	Gaur/banteng	2
	Cervidae Goldfuss, 1820	–	–	Deer	1
		Muntiacus Rafinesque, 1815	–	Munjac	15
	Suidae Gray, 1821	*Sus* Linnaeus, 1758	*Sus scrofa* Linnaeus, 1758	Boar	35
Primates Linnaeus, 1758	Cercopitheciae Gray, 1821	*Macaca* Lacépède, 1799	–	Macaque	14
	Hylobatidae Gray, 1870	*Hylobates* Illiger, 1811	–	Gibbon	4
Carnivora Bowdich, 1821	Felidae G.Fischer, 1817	*Pardofelis* Severtzov, 1858	*Pardofelis marmorata* (Martin, 1837)	Marbled cat	9
Rodentia Bowdich, 1821	–	–	–	Rodent	6
Chiroptera Blumenbach, 1779	–	–	–	Bat	1
Galliformes Temminck, 1820	–	–	–	Galliform	6
Testudines (Batsch, 1788)	Testudinidae Batsch, 1788	*Indotestudo* Lindholm, 1929	*Indotestuda* elongata (Blyth, 1853)	Elongated tortoise	8
		Manouria Gray, 1854	*Manouria emys* (Schlegel & Müller, 1840)	Asian forest tortoise	22
Squamata Oppel, 1811	Varanidae Merrem, 1820	*Varanus Merrem, 1820*	–	Varanus	4
Amphibia Gray, 1825	–	–	–	Amphibians	2
Osteichthyes Huxley, 1880	–	–	–	Fish	1
NISP	–	–	–	–	130
Unidentified mammals	–	–	–	–	26
Unidentified remains	–	–	–	–	68
TOTAL					**224**

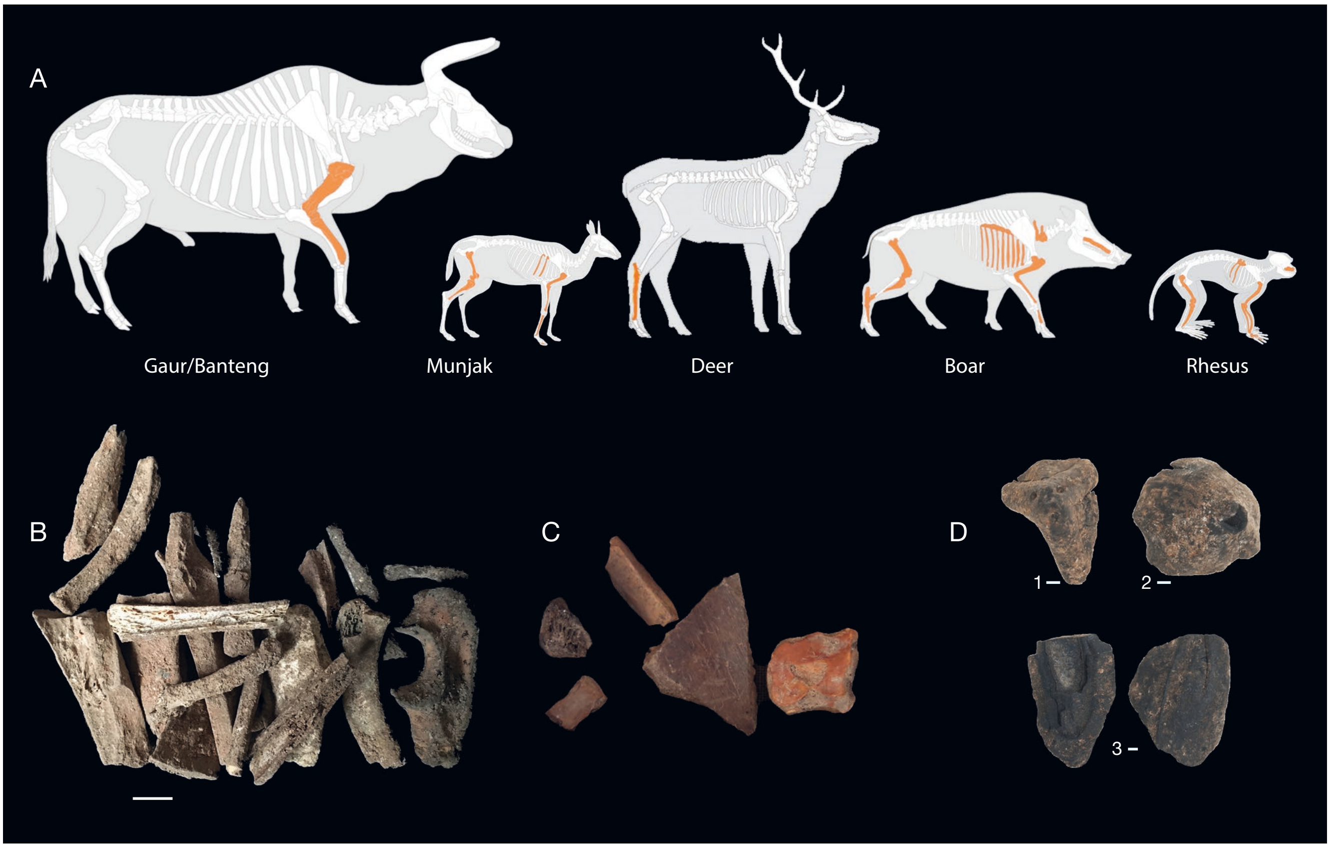

FIG. 15. — Archaeozoological and archaeobotanical remains from Hiem Cave: **A**, anatomical distribution of mammalian remains from Hiem; **B**, state of preservation of osteological materials; **C**, burnt bone fragments; **D**, *Canarium* sp. fragments: **1**, apex; **2**, base; **3**, central (middle) parts of nut. Scale bars: B, 1 cm; D1-3, 1 mm. Photos credits: Archaeological Museum in Gdańsk (D).

TABLE 4. — Hiem Cave. List of molluscs occurring in the sediment sequence.

Environment	Class	Family	Genus	Species	Number of shells
Terrestrial	Gastropoda Cuvier, 1797	Cyclophoridae J.E.Gray, 1847	*Cyclophorus* Montfort, 1810	*Cyclophorus* spp.	56
				Cyclophorus spp. *operculum*	3
		Camaenidae Pilsbry, 1895	*Camaena* Albers, 1850	*Camaena vanbuensis* E.A.Smith, 1896	1
				Camaena sp.	3
		Clausilioidea Gray, 1855	*Garnieria* Bourguignat, 1877	*Garnieria* sp.	2
			Nienauchenia	*Nienauchenia dautzenbergii* (Morlet, 1893)	1
Aquatic	Gastropoda	Pachychilidae P.Fischer & Crosse, 1892	*Brotia* (*Antimelania*) P.Fischer & Crosse, 1892	*Brotia* (*Antimelania*) sp. Typ a	35
				Brotia (*Antimelania*) sp. Typ b	20
		Viviparinae Gray, 1847	*Viviparus* Montfort, 1810	*Viviparus* spp.	2
		Unionidae Rafinesque, 1820	*Lanceolaria* Conrad, 1853	*Lanceolaria* spp.	3
			Nodularia Mertens, 1822	*Nodularia* sp.	4
			Undefined	–	9
		Ostreidae Rafinesque, 1815	Undefined	–	1
TOTAL					**140**

series of unifacial centripetal blows detached from the convex face at a stage of decortication and shaping (White & Gorman 2004; Marwick 2018; Forestier *et al.* 2021a, b; Yinghua *et al.* 2021). Working edge was created with series of small unifacial scars mostly on distal and side parts.

Moreover two debitage sequences have been observed (Figs 9; 10; 12). In both cases, natural striking platforms without traces of preparation were used. First core reduction was based on the unidirectional flaking with changed orientation at the last stage. Cylindrical shaped basaltic cobble was used as a raw material. Scar pattern analysis shows that negatives detached in the first series of blows are very invasive and most of the flakes had a feathered termination; different looks situation with other stages of core reduction – the next series of scars are smaller and also numerous hinges are visible on the flaking surface. This is probably the result of the lack of a flaking angle control and a rejuvenation of the striking platform (Fig. 9). Knappers missed this problem by changing the orientation of core reduction. This method shows similarities to APS shaping sequence known from Moh Khiew Cave site (Forestier *et al.* 2021a, b) Second sequence combines debitage and shaping (Fig. 10). Bipolar reduction on the anvil was used in the first stage of flaking of the cylindrical-shaped cobble (core). Distal part of the block was shaped with invasive centripetal blows and the edge was retouched (shaped tool). Bipolar technique has been widely observed in late Pleistocene and Holocene assemblages from MESA and China territory (Forestier *et al.* 2013, 2021a; Li *et al.* 2019; Zhou *et al.* 2020). However, this technique was mostly used for sumatralith blank production from splitting of cobbles or small blanks for the production of retouched flake tools (Zhou *et al.* 2020; Forestier *et al.* 2021a).

The presence of numerous flakes with a completely decorticated dorsal side shows that most of the products were detached in a late phase of core reduction (White & Gorman 2004). However, the small size of assemblage discovered only in test pits cannot assume that cores were transported to the site in decorticated form with a prepared flaking surface (White & Gorman 2004).

The analysed artefacts revealed a rather low degree of use. The tools were probably utilised in an ad hoc manner, only for a short period of time. A similar pattern was observed at numerous sites in south-east Asia. It was suggested that lithic industry was supplementary and served to create and maintain the technology based on light organic materials (Xhauflair *et al.* 2016). Moreover, blank forms could not be related directly to the performed task. Instead, whenever the need arose, the most suitable flake was selected (Borel *et al.* 2013). Due to the small sample size and even lower percentage of use, its interpretation requires caution. It could be suggested that bigger and thicker flakes were used on harder materials, whereas more gracile artefacts were used for plant working.

The lumps of minerals were most probably intentionally brought to the cave. Traces of the red substance containing iron were also recorded on the working surface of the limestone quern mentioned above, found at the depth of 110 cm (Fig. 13). Thus, the raw material was processed and probably pulverised. Both minerals have also been found at other Hoabinhian culture sites, e.g. large amounts were identified in the Xom Trai Cave. Characteristically, both substances have been used till today by some communities in Vietnam. The first is used as a diet supplement, the other is taken by pregnant women. It is assumed that the minerals may have played a similar role in Hoabinhian societies (Viet 2015) – which seems to be confirmed by the findings from Hiem. Hematite was probably pulverised to render it easier for consumption as a supplement of other foodstuffs. Quite importantly, hematite or ochre are diet supplements for many traditional peoples in various regions of the world. This phenomenon, known as geophagia or pica, is especially popular among women and children supplementing a sudden shortage of minerals in the body (Parry-Jones & Parry-Jones 1992; Abrahams 1997; Ziegler 1997). On the other hand, Hoabinhian societies deposited lumps of ochre and hematite in graves and used them as dyes, which is confirmed by the analysis of petroglyphs (Lebon *et al.* 2019). However, these various ways of using the raw material do not contradict each other in any way.

Environment exploitation

The results of archaeozoological analysis unambiguously show that most of the fauna remains from the Hiem Cave were connected with the presence of humans. The assemblages are evidently intentional and selective, which is substantiated by absence of many species typical of rainforest animals – from elephants to big predators, to small mammals weighing less than 500 g. The component which may be considered "natural" is individual bones of a small rodent, bat and amphibian, while the remains of even-toed ungulates, monkeys and big reptiles constitute a clear proof of consumption, which is substantiated by their anatomical distribution and the evidence of use of fire found on the bones. Predomination of the remains of the most attractive parts of carcass, their fragmentation and almost complete absence of elements unattractive in terms of consumption (skulls or teeth) prove that the place where they were discovered was where the meat had been eaten, while flaying must have taken place somewhere else. It seems that only monkeys could have been brought to the cave in whole.

It seems that the main factor in hunting selection was how easy it was to acquire meat, which is confirmed by predomination of the remains of the wild boar – hardly a timid animal – and the tortoise. More timid animals, requiring more complex hunting strategy, constitute a decisive minority in the Hiem Cave assemblage. The model of meat consumption identified in Hiem is confirmed by the currently available knowledge (Piper & Rabett 2009; Pawlik *et al.* 2014; Forestier *et al.* 2015; Amano *et al.* 2016; Conrad *et al.* 2016).

Archaeozoological data seem to point directly to the environmental conditions in which the population in Hiem functioned and what ecosystem they exploited. All the animals whose remains were discovered in the cave are connected with the rainforest habitat. The contribution of the species inhabiting more open ecosystems (e.g. the varan, big predators, big ungulates) is minimal or even absent. The assemblage is coherent in terms of paleoenvironment identification.

Most of fauna materials connected with Hoabinhian populations contain the species proving exploitation of various ecosystems (Table 4): forests and more open areas. This apparent contradiction is usually explained with chronological diversification of sites. However, it is the exploitation of the rainforest paleoenvironment that is the most characteristic feature of these communities in south-east Asia, both in the late Pleistocene and early Holocene.

Table 5. — Hiem Cave. List of botanical findings. Abbreviation: **Sqm**, square meter.

Level (cm)	*Canarium* sp. Apex	base	Central fragment	total	Weight (g)	Others
Sqm A						
90-100	5	19	487	511	31	Amorphic fragments
100-110	8	11	415	434	19.13	–
110-120	2	4	43	49	3.64	–
Sqm B						
90-100	3	11	358	372	16.77	–
110-120	–	–	6	6	0.41	–

The continuous and abundant occurrence of mollusc shells along the 1.5 m profile of the deposits excavated at the Hiem site (Table 4) is concurrent with archaeological findings from other caves and rock shelters inhabited by the Hoabinhian, where snail and mussel shells constitute a considerable fraction of the sediments (Viet 2004). The richness of mollusc shells indicates that those invertebrates were an important food source for the Hoabinhian. Collecting molluscs is regarded as a traditional Hoabinhian food strategy (Viet 2004).

The taphocenosis dominated by *Cyclophorus* spp., an operculated land snail living on the limestone bedrock in tropical and subtropical south and south-east Asia (Do & Do 2019), and *Brotia* (*Antimelania*) spp., freshwater snail preferring low energy zones, e.g. river banks, is similar to the findings from a range of archaeological sites in Vietnam, including Con Moong (Viet 2004). Co-occurrence of land and aquatic mollusc shells in the deposits indicates exploitation of different natural food resources by the Hoabinhian people. *Cyclophorus* spp. and rock crab *Ranguna* spp. were collected during the warm and rainy season, i.e., between April and October, in the local limestone mountains. On the contrary, stream snails could have been collected all year round. Based on an equal share of *Cyclophorus* spp. and *Brotia* spp. shells in the deposits (Table 4), it is suggested that local people did not have to move seasonally – food was available all year round. What could force people to migrate to new sites was overexploitation of natural resources. This scenario is suggested for the Hoabinhian people, who inhabited the nearby Xom Trai cave (Viet 2004). In northern Vietnam moist phases 12 000-10 000 BP with the peak in *c.* 10 500 BP and 9500-9000 BP with the peak in *c.* 9300 BP correspond to the increase in land snail *Cyclophorus* spp. and crab *Raguna* spp. at the archaeological sites (Viet *et al.* 1983). The smoothed limestone found in the cave sediments was formed as a result of increased karst processes – chemical weathering, favoured by a warm and humid climate. The contribution of humus to the sediments is also indicative of warm climatic conditions.

The study of archaeobotanical materials can help to understand the process of formation of sedimentary layers inside the caves. It also brings data on the use of plants as well as sheds light on the former human interaction with the surrounding nature (Cappers & Neef 2012). The finds from Hiem clearly indicate that nuts were exploited by the local group of people.

Canarium genus represents evergreen trees of Burseraceae family characteristic for tropical and subtropical zones of Asia and Africa (Ellen 2019). Some species have edible kernels and the tradition of tree-nuts exploitation is well described for southeast Asia including Vietnam. Nuts provide fats, proteins and vitamins, although not too much carbohydrates (Deng *et al.* 2019). We can assume that nuts from Hiem were an element of the nutrition strategy. This is also supported by the fact that *Canarium* finds were accompanied by postconsumer assemblages of mollusc shells. Presence of snail as *Cyclophorus* spp. as well as rock crabs (*Ranguna* sp.) may indicate a warm or rainy season as a time of collecting. In addition, such finds are known from other caves in Vietnam (Viet 2004, 2008) and neighbouring areas (Paz 2005; Deng *et al.* 2019).

Taking into account the finds of *Canarium* sp. and the archaeozoological results, it can be assumed that the inhabitants of the cave in Hiem penetrated the local evergreen broad-leaved forests.

It is interesting that the shells of *Canarium* bore traces of scorching and sometimes burning. Possibly the hunter-gatherers from Hiem roasted *Canarium* as such a procedure facilities nut cracking and grinding (Divišová & Šída 2015).

CONCLUSIONS

Excavations in the Hiem Cave, situated in the mountainous area of monsoon forests, yielded remains of the early Holocene settlement, which, according to the results of radiocarbon dating, may be determined as *c.* 8500-8200 cal BC. The complete stratigraphic sequence recorded in the cave did not reveal layers older than the Holocene.

The data from the Hiem Cave testify to the extremely meticulous use and obtaining of all sources of food. The adaptation strategy does not show signs of narrow specialization, but rather the exploitation of a wide spectrum of fauna and edible vegetation. The sources of such an economic model should be seen in the relatively narrow range of the availability of edible animals and plants as well as high demand for food, which could result from the growing demographic pressure.

In comparison with the caves situated, e.g. in the area of the Muong Vang Valley, in easily accessible places, such as the Xom Trai Cave, the settlement seems less stable. The paleoecological sources from Hiem show that the human groups inhabiting the cave exploited the closest vicinity implementing typical tool kits displaying evidence of ad hoc use. The cultural sequence of pottery finds recorded in the Hiem Cave (the Da-But, Phùng Nguyên, Go Mun cultures) indicates younger, post-Hoabinhian chronology of the settlement and has its exact analogy in the Xom Trai Cave (Gralak & Nguyen, in press).

The multifaceted data we have obtained on the adaptation strategies of early Holocene communities also find analogies in ethnological data. This is another premise for a discussion on the durability and effectiveness of the adaptation model chosen by communities associated with the Hoabinian technocomplex. The short-term occupation of rock shelters related to the exploitation of the environment during the rainy season is a model practiced by modern hunter-gatherers, e.g. the Mani people living in Southeast Asia. Outside of the rainy season, this community leads a nomadic lifestyle, building temporary shelters. It is quite possible that the creators of the Hoabinhian culture resorted to a similar strategy. Quite significantly, according to recent genetic research, the modern-day hunter-gatherers are their distant descendants (McColl *et al.* 2018).

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