PLEISTOCENE TO HOLOCENE STRATIGRAPHY OF AZOKH 1 CAVE, LESSER CAUCASUS

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(Received 26 October 2010. Accepted 13 December 2010.)

Abstract

Azokh Cave is located in the southern Caucasus and contains a Pleistocene and Holocene sediment infill. The site is significant due to its geographic location at an important migratory route-way between the African subcontinent and Eurasia, and the recovery of Middle Pleistocene hominid remains in the sedimentary sequence during a previous phase of excavation. The stratigraphy of the largest of the cave's entrance passages, Azokh 1, is described in full in this paper for the first time. It is broadly divisible into nine units. Our investigations have shown that the stratigraphy splits between two spatially isolated sequences. The upper of these two sequences has proven to be fossiliferous and has yielded many types of mammal (macro and micro) fossils as well as evidence for human occupation. The base of this fossiliferous (upper) sequence is dated at around 300ka whilst the uppermost level appears to be largely confined to the Holocene (≈150 years BP).

Introduction

Azokh Cave is located in the mountainous terrain of the Lesser Caucasus at 39°37.15' north and 46°59.33' east (Fig. 1). This mountain range spans the eastern side of the Caucasian isthmus between the Caspian Sea and the Black Sea and is the result of a fold system, which forms part of the broader, hemispherical-scale, Alpine–Himalayan mountain range (Buryakovsky *et al.* 2001; Saintoti *et al.* 2006; Dilek *et al.* 2009). The Lesser Caucasus represents the southern expression of a wide zone of elevated topography and is separated from the parallel trending Greater Caucasus further north by the Kura Lowlands, an intermontane basin infilled with Palaeogene to Quaternary molasse deposits (Fig. 1c).

The cave is currently situated at an elevation of about 850m and constitutes what remains of a larger karst system, which is now abandoned and has suffered erosion. The host bed-rock is a thickly bedded Mesozoic limestone, which Lioubine (2002) considered to be part of the Jurassic calcareous massif. Chert development is widespread at several levels in the limestone and appears to have played an important role in cave chamber formation and roof stabilisation. At present, accessible sections of the cave consist of a broadly NNE to SSW-trending series of chambers, which are transected on their western flank by several WSW to ENE-trending passages connecting to the exterior (Fig. 2).

This paper will provide background information on the history of excavation work at the cave, emphasizing its significance from a palaeoanthropological perspective. The cave-fill stratigraphy of Azokh 1, the largest of the passages leading to the cave interior (Fig. 2b), will be described in detail for the first time. This work is based primarily on field observations and measurements. A brief description of the more prominent fossil finds (to date) is also included, along with some preliminary conclusions.

Irish Journal of Earth Sciences **28** (2010), 75–91

doi: 10.3318/IJES.2010.28.75

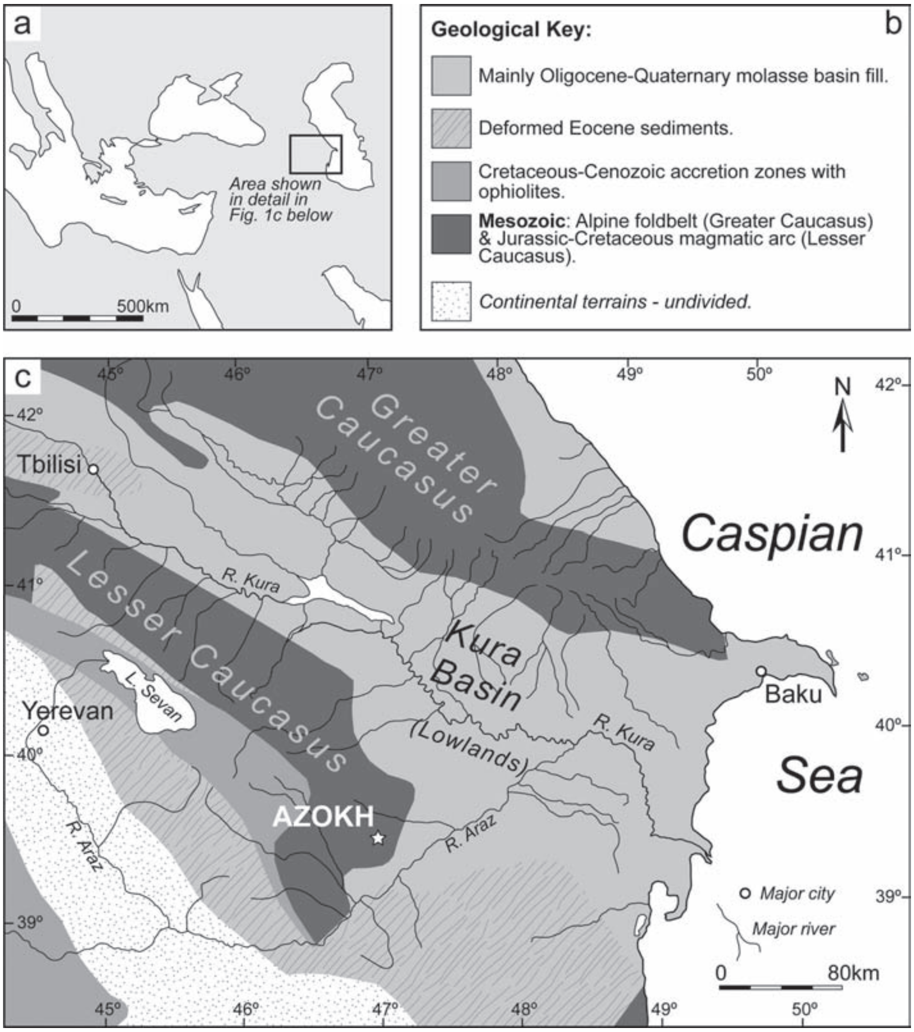

Fig. 1—(a) General location map. The inset box shows the location of the detailed map presented in Fig. 1c; (b) Key to geological units in Fig 1c; (c) Simplified geological map of the region showing the location of the Azokh Cave site (shown with a star). Geographic and hydrographic information has been sourced from UN Map No. 3761, Revision 6, 2007. Geological information has been adopted and modified from that of Brunet *et al.* (2003).

Excavation work and significance of Azokh Cave

Azokh Cave has been an important site for palaeoanthropological studies since its initial excavation by Huseinov in the 1960s (Mustafayev 1996; Lioubine 2002). Excavation at the site from the 1960s until 1988 focussed almost exclusively on the largest of the entrance passages (currently termed Azokh 1). The excavations, which took place during the Soviet era, uncovered a large quantity of faunal remains and stone tools, as well as several hearth layers (see Fig. 3 for an indication of the amount of sediment removed). Huseinov initially defined 10 stratigraphic horizons infilling the chamber, which was increased to 17 by Veilicko in 1979 and then to 25 by Gadzhiev in 1980 (reported in Huseinov 1985 and Lioubine 2002). In 2002 an international team was invited by the regional authorities to restart excavations at the site (Fernández-Jalvo *et al.* 2004). To date, the current phase of systematic excavation at Azokh, using an aerial grid and three-dimensional spatial recording of finds, has focussed primarily on the upper half of the sedimentary sequence remaining in Azokh 1 (Fig. 3a). Preliminary geological and archaeological surveys have also been conducted in two of the other passages at the cave: Azokh 2 and 5 (Fig. 2).

The significance of Azokh Cave became apparent in 1968, when a human mandible fragment containing a single intact molar was found somewhere in the midsection of the sedimentary infill of Azokh 1. This was later determined by Kasimova (2001) as being Middle Pleistocene in age and pre-Neanderthal in character. Unfortunately, a degree of uncertainty persists to the

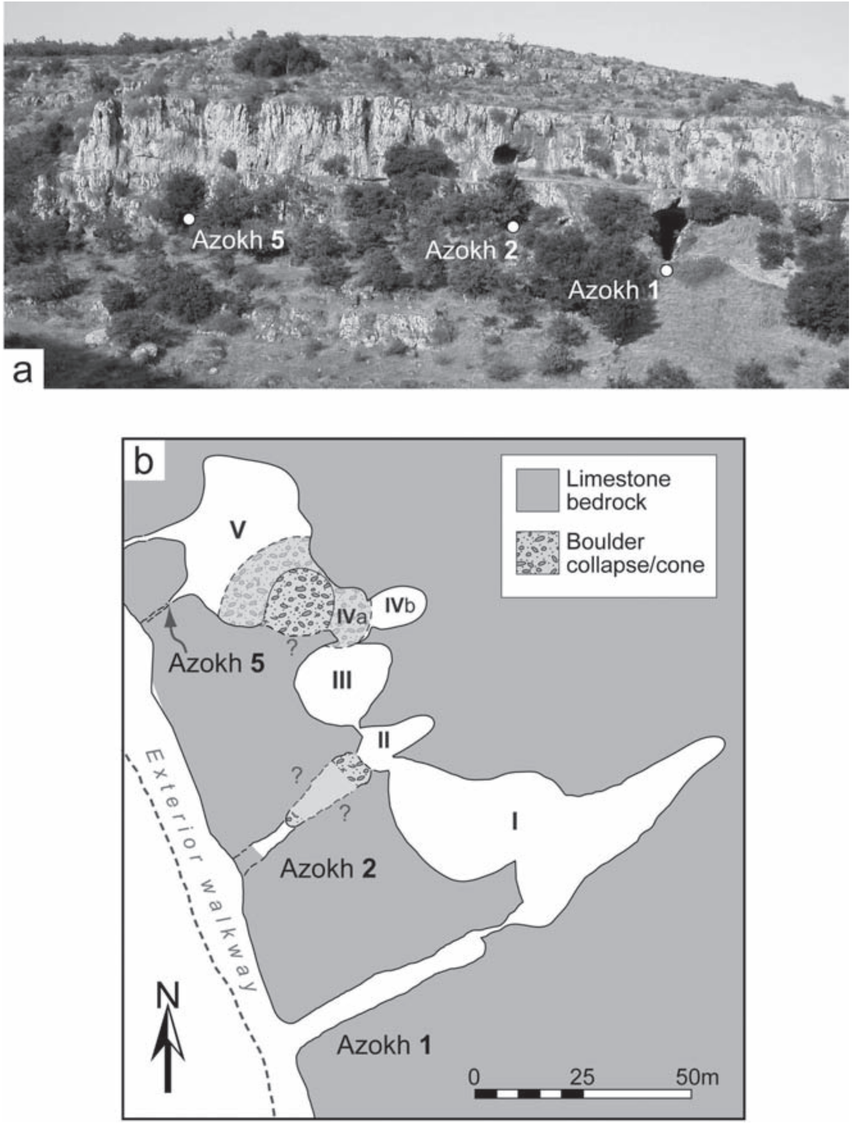

Fig. 2—(a) View of hillside containing Azokh Cave system (photographed facing eastwards). Locations of entrance passages Azokh 1, 2 and 5 are indicated with a white circle; (b) Plan-view sketch map of the cave system showing the location of the main entrance passages. Internal chambers to the cave are labelled I–V.

present as to the exact azimuth of this find, particularly as systematic three-dimensional coordinates were not employed for excavation during this period.

Azokh Cave's geographic location and its cache of fossils have the potential to enhance our understanding of patterns of early human occupation in the Caucasus region and may also help to test the robustness of early hominid migration theories. The fossil finds from Azokh, combined with other discoveries from the region, including Dmanisi in southern Georgia (Gabunia *et al.* 2000; Oppenheimer 2004) and Mezmaiskaya in the Russian Caucasus (Skinner *et al.* 2005), have challenged the proposal that the Caucasus acted as a topographic barrier to hominid migration (Fernández-Jalvo *et al.* 2004). The Dmanisi find, dated at *c*. 1.75 million years, represents one of the oldest examples of genus *Homo* outside Africa and is thought to be an evolutionary grade falling between *H. habilis* and *H. erectus* (Martinon-Torres *et al.* 2008; Rightmire *et al.* 2006).

The Middle Pleistocene *Homo heidelbergensis* specimen (Kasimova 2001) from the middle of the sedimentary sequence in Azokh 1 is believed to be the most oriental representative of this particular group. Evidence of human occupation by Neanderthals, indicated by the lithic technology, occurs in the units, which lie above this level, thus allowing the opportunity to potentially study this particular transition.

Introduction to stratigraphy of Azokh 1

The need for a clearly defined lithostratigraphic framework for Azokh 1 has been apparent for some time now. In a review of the site Lioubine (2002) reiterated several times the fact that the original excavation at Azokh did not formally define units lithologically, preferring instead to characterise them archaeologically, and, most importantly, did not provide, unambiguous, thickness estimates for the horizons defined within the succession. Another major problem, according to Lioubine (2002), is that lateral variations in bedding horizons, moving from the cave entrance to the interior, were never properly considered or indeed recorded.

It should thus be noted that the following description of the stratigraphy of the cave fill is based on what actually remains since the time of the initial excavations. According to Lioubine (2002), when the cave was discovered, sediments were 3m from the roof of the cave. The complete sequence, from the top (Unit I) to the base (Unit IX), should have been recorded at the cave entrance before excavations started in the 1960s. The extent of the remaining cave fill is shown in Fig. 3a, which also provides an indication of the original fill of the cave. Almost no sediments remain along the sides of the cave walls, making assessment of lateral continuity and facies variation difficult.

The Azokh 1 passage runs for approximately 40m in a WSW–ENE direction. The roof is arched, rounded and, to a degree, smoothed, and has the appearance of a partial phreatic tube (Ford and Williams 2007). As the water-table lowered subsequently water flowing through this passage cut down through the underlying bed-rock, producing a tall, and relatively narrow cave profile (Fig. 3b) reminiscent of a keyhole shape. At the midway point in the passage, the gap between the roof and floor is between 11 and 11.5m. Moving from this midpoint towards the entrance-way, the floor cuts down into a lower level forming what has been described as 'the basal trench' (see Fig. 3a). The distance here between floor and roof is *c*. 14m. The net result of the drop in the floor level of the chamber is that the remaining *in-situ* sediment infill is actually two separate sediment sequences, which can no longer be readily correlated due to removal of all of the intervening stratigraphy (Fig. 3a). This will be considered in further detail later on.

Sediment Sequence 1

This section is exposed in the basal trench and in the sediment pedestal, which characterise the entrance to the chamber. Approximately 4.5m of section remains (Fig. 4); however, due to the shape of the cave floor, this section wedges out towards the base (Fig. 3a) and little remains of the lowermost units. The stratigraphic succession is as follows (from the base upwards):

Unit IX

Unit IX can be subdivided; the base (Subunit IXb) varies between 110 and 125cm in thickness and is a massive creamy-tan loam to sandy loam, which is quite firm and non-calcareous. It lacks any internal structure and has granules of cave rock dispersed throughout. This subunit drapes the irregular surface topography of the bed-rock and the basal 50–60cm contains concentrations of pebble-grade 1–5cm sub-angular to sub-rounded chert/chalcedony and decalcified limestone clasts. These appear to form poorly defined bedding parallel (clast-supported) seams or pockets. The top *c*. 60cm of IXb is much more uniform and massive in character and clasts are rare.

Subunit IXa (at the top of Unit IX) measures between 70 and 85cm and is a firm non-calcareous creamy-tan granular loamy sand (with a significant silt component also). It is quite porous and the strong medium to coarse granular texture is the distinguishing characteristic from the underlying subunit. The actual contact is gradational in detail, with the granular texture developing over a stratigraphic distance of about 15cm. The subunit contains a matrix-supported population of sub-rounded to angular limestone and chert clasts, ranging 2–6cm on their longest axis.

Unit VIII

This horizon ranges in thickness from 20–30cm when examined orthogonally to the axis of the chamber (it thins away from the cave walls towards the centre of the chamber). It also thins to nothing over a short distance moving back into the cave interior and is likely to be a localised feature. It is a poorly sorted friable conglomerate, which is dominantly matrix-supported; however, it appears to approach clast-supported in places. The matrix is somewhat finer than the underlying units and is a loamy sand with a persistent medium granular texture. Clasts are generally composed of sub- to well-rounded cherts and decalcified limestones. Some angular chert fragments, presumably more locally derived, are also present. Clasts are seen on all scales from gravels up to about 5–6cm pebble/cobble grades. Rare larger clasts, including one 19cm block of limestone, are also present. The contacts with the enclosing units are indistinct and Unit VIII appears to represent an increase in gravel and pebble material within essentially the same host sediment.

Unit VII

This unit is 110–15cm thick, friable, non-calcareous and light to medium greyish-brown in colour. The texture

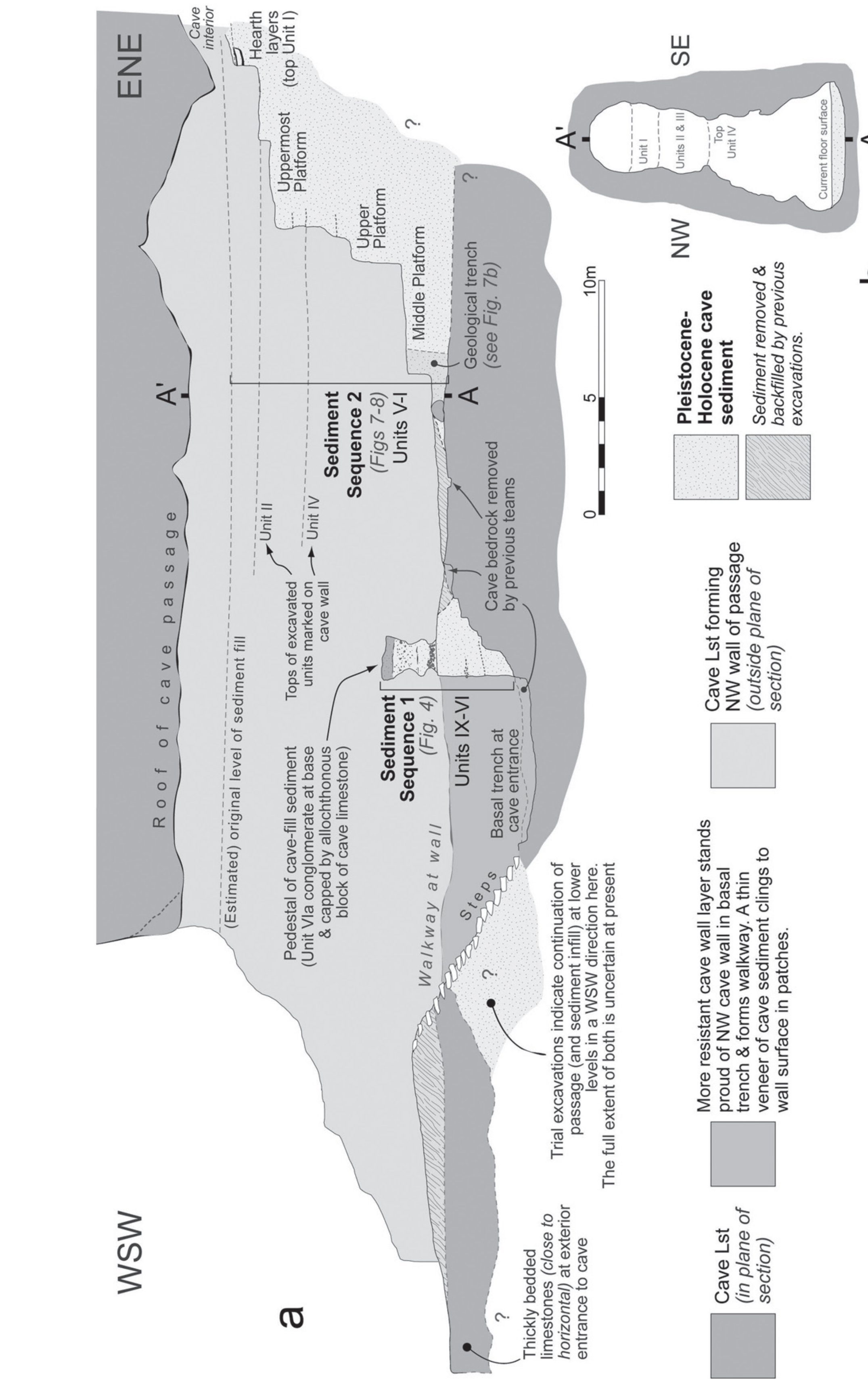

Fig. 3—(a) Sketch cross-section through Azokh 1 Passage (drawn facing NW). The estimated amount of cave-fill sediment removed by previous excavation teams is indicated by the upper dashed line. The floor of the passage is illustrated insofar as its extent is currently known and the height of the roof was measured at various points along the section using a telemeter with an accuracy of *c.* 1cm. The locations of the stratigraphic sections used to compile the logs in Figures 4, 7 and 8 are also indicated; (b) Cross-section (A–A') across the axis of the passage (orthogonal to 3a and drawn to the same scale) indicating levels of sediment infill.

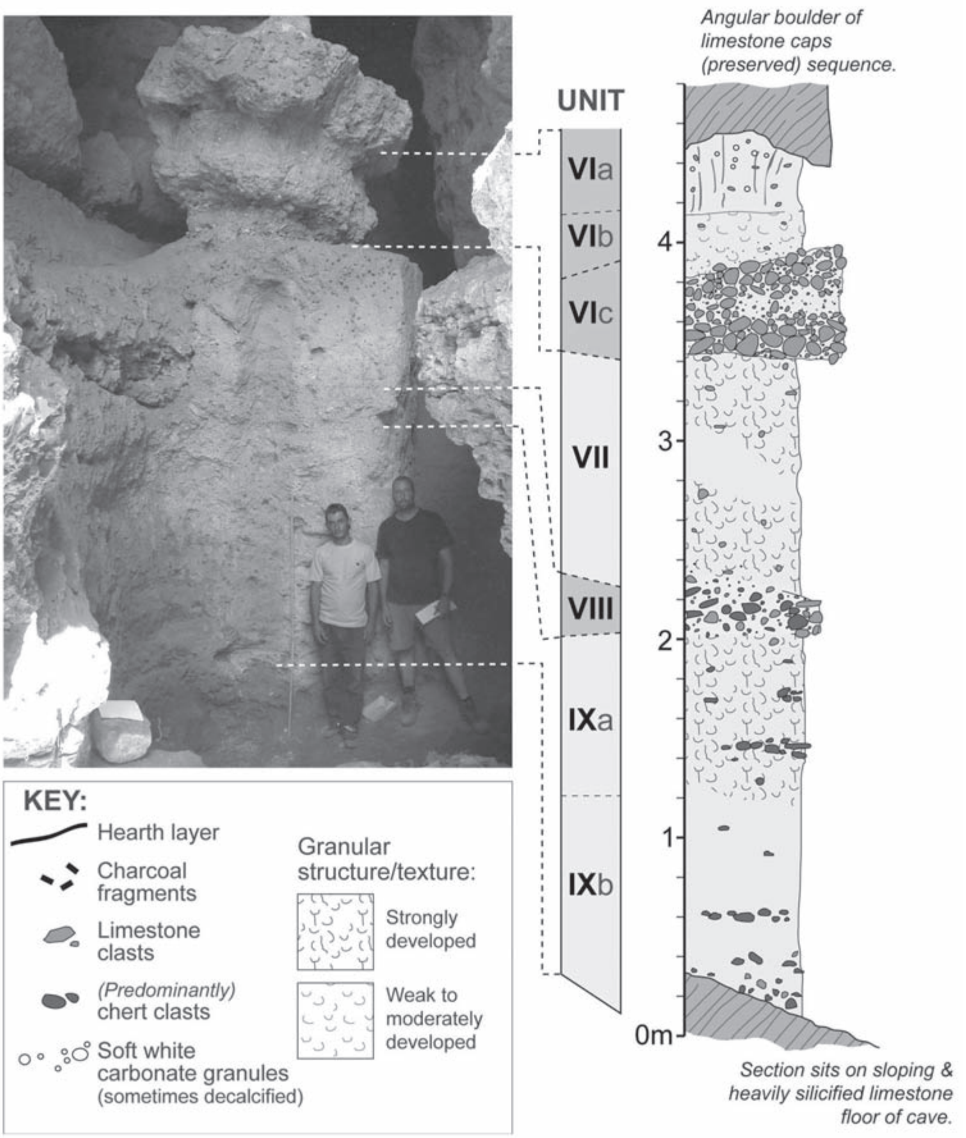

Fig. 4—Stratigraphic column for Sediment Sequence 1 in Azokh 1 Passage. Unit numbers are indicated in the central column with roman numerals. The photograph of the actual section to the left of the column is for reference and indicates precisely where the boundaries of the units have been set. Much of this section is exposed in the basal trench in the entrance to the cave (see Fig. 3).

varies from loamy sand near the base, through loam and up to clay loam at the top, the overall trend being an upward increase in the percentage of fines. Gravel to small pebble-grade chert and decalcified limestone clasts are dispersed throughout; however, they appear to become rare in the midsection. The contact with underlying Unit VIII is gradational and is marked by a notable drop in clast content. A strong fine to medium granular texture is developed in the basal 48–60cm and also the top 30–50cm, while the midsection is more massive in consistency.

The top 4–5cm of Unit VII loses the granular texture completely and forms a lithified ‘crust’. A sample of this particular horizon was resin-mounted and thin-sectioned (Fig. 5) and shown to be composed of very fine-grained sediment with extensive iron-oxide coating. Interspersed in this matrix are larger grains of quartz, plagioclase feldspar, mica and possible serpentine. Lithic clasts of limestone, chert and tuff also occur. The occurrence of tuff and, in particular, plagioclase feldspar in the sediment is interesting as it implies derivation from an igneous source. Several (intrusive and extrusive) igneous rock locations have now been identified in the surrounding valley.

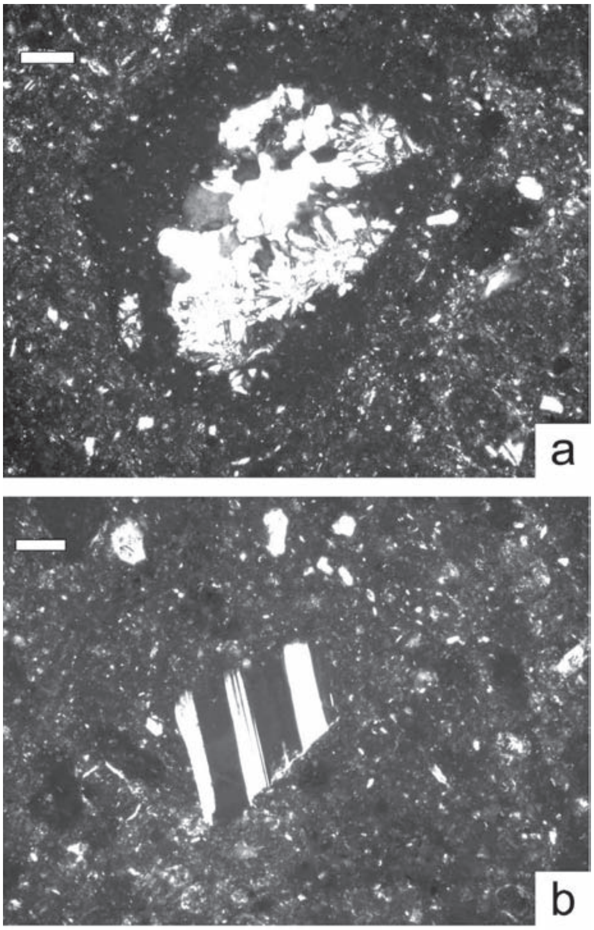

Fig. 5—Photomicrographs of resin-mounted thin-sections of sediment taken from the top of Unit VII; (a) Polycrystalline chert clast in fine-grained groundmass showing incipient radial structures; (b) Plagioclase feldspar grain in fine-grained groundmass showing lamellar twinning. Both (a) and (b) are seen in crossed-polarised light, scale-bars 100μm.

Unit VI

This unit is divisible into three horizons; the lowest of which (Subunit VIc) is perhaps the most conspicuous in the entire succession. It varies in thickness between *c*. 30 and 60cm (averaging about 35cm in the centre of the cave) and is a friable to loose clast-supported pebble to cobble conglomerate (Fig. 6). Clasts are generally sub- to well-rounded and are composed predominantly of tan-coloured cave limestone with a yellowish weakly calcareous weathering rind. Size ranges are typically 1–7cm; however, larger clasts are also encountered, including a *c*. 40cm angular block of chert, which appears to have dropped into place from the roof of the cave above. Exposure of VIc is extremely limited; it is now preserved only at the foot of the pedestal of sediment, capped by a large boulder of cave limestone close to the entrance of the cave (Fig 3a). The transition from the underlying unit is marked essentially by a marked increase in pebble-grade clasts. In addition, abundant bone remains were discovered in one particular section of the contact.

Subunit VIb lies directly above the conglomerate (the contact is gradational) and is 30–33cm thick. It is a very firm (especially in the base) pink-buff loamy sand with a significant gravel component. This loamy sand texture then passes subtly to a sandy loam, with a high clay content, towards the top. Subunit VIb is calcareous and has weakly developed fine to medium granular texture (it could be considered transitional between massive and granular). Flattened and degraded white carbonate clasts are common in parts of the base and smaller rounded and angular gravel and pebble grade clasts are present throughout. Bone fragments are present, but not common in this subunit.

The final horizon of Sequence 1 is Subunit VIa, which varies in thickness between 10–40cm. This variation is due to the irregular underside of an overlying 50–110cm angular boulder of limestone, which caps the preserved sequence and looks to have dropped into place. The texture of VIa varies between a clay and a clay loam and it is similar in colour to VIb below. The contact between the two subunits is somewhat gradational and the impression is of an increase in clay percentage moving up through the sequence. VIa has a moderate granular texture with an additional prismatic component due to the development of sub-vertical peds. It is friable, soft and weathers back and contains abundant mm-scale white carbonate clasts (possibly nodular caliche). Bone and charcoal fragments were also noted in this subunit.

Sediment Sequence 2

This section has been reconstructed from several sections exposed as a series of steps or platforms, which climb through the stratigraphy towards the rear of Azokh 1 passage (Fig. 3a). The composite stratigraphy for Sequence 2 is presented in Fig. 7 and continues on Fig. 8. All of the excavation by the present team in Azokh 1 has been focussed in this area.

Unit V

Unit V is *c*. 4.55m thick and is dominantly fine-grained in character. Subunit Vb, at the base, is between 220–30cm thick and is best exposed (at present) in a small trench, initially excavated in 2002 (see 'Geological trench' in Fig. 3a). The succession recorded in this trench (Fig. 7b) from bottom to top is as follows:

a) The base of Vb is a 50–6cm horizon of (purple-weathering) brown stiff non-calcareous clay,

Fig. 6—View of Subunit VIc conglomerate. The enclosing horizons (Unit VII and Subunit VIb) are also visible in the bottom and top (respectively) of this photo. Scale-bar = 21.5cm approximately.

which rests directly upon the floor of the cave. Gravel content in this bed increases towards the top; however, it remains dominantly clay-rich.

b) The overlying bed is *c*. 20–30cm of variable soft and crumbly yellow-tan clay-rich silt, which has a noticeable gravel content. Stratification is evident with layered horizons showing a colour gradation. Overall, this unit shows a clear transition of colour from the base to the top, where it is darker and more reddish-brown.
c) The following horizon is similar in composition to (b); however, it is conspicuous in that it appears to form a lens or 'channel' structure, which cuts down into the underlying strata. This lens is 50cm thick, but tapers out completely over a lateral distance of 70cm. Angular dark chert clasts were also noted in the matrix.
d) 40–47cm of reddish-brown, soft non-calcareous clay loam follows, with common, but dispersed angular limestone clasts. The base is substantial in structure, becoming weakly granular towards the top.
e) The top of the section in the trench is *c*. 20cm of very stiff dark reddish-brown clay, which is weakly calcareous and contains common small soft (decalcified) white carbonate granules. These were present also in (d), however, they were much more dispersed. Horizon (e) continues from the trench section on the far side of what has been termed the 'Middle Platform' (see Fig. 3a) for a further stratigraphic distance of 35–40cm. The top of the bed here is capped in places by a thin 1cm cream-white to white non-calcareous crust and this is taken to mark the top of Subunit Vb.

The overlying subunit (Va) is *c*. 220–230cm thick and presents a steep vertical face in the section towards the rear of the cave. For safety reasons, the exposed face of this particular part of the succession in has not been thoroughly cleaned back. As a result, Va is treated as a single subunit for the present; as future excavation work progresses the resolution of the internal stratigraphy of this part of Unit V will no doubt improve.

There is a notable increase in clay and carbonate content moving up through Subunits Vb and Va. The

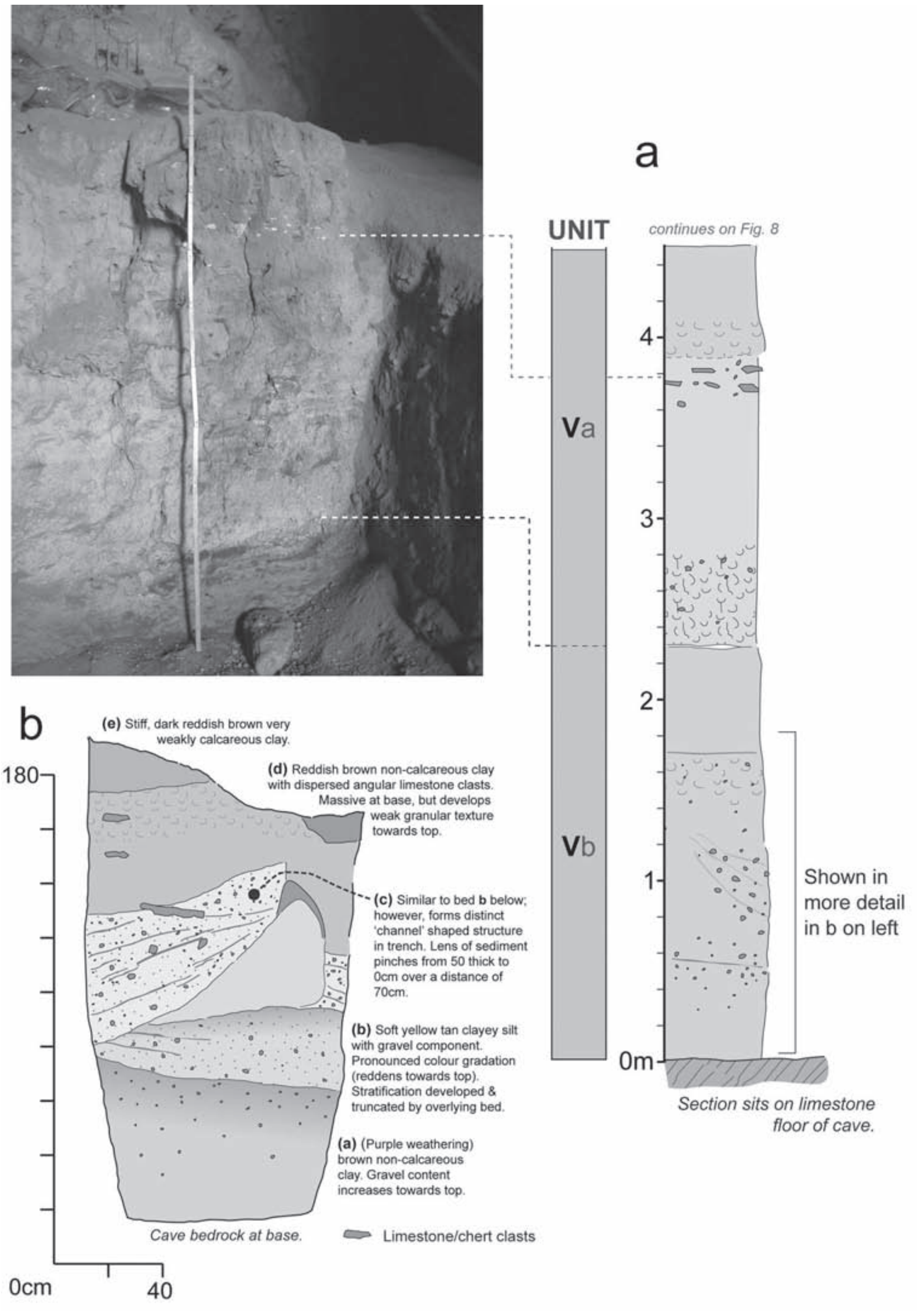

Fig. 7—(a) Composite stratigraphic column for the base of Sediment Sequence 2 in Azokh 1 Passage. The height of the wooden ruler in the photograph is 2m. See Fig. 4 for key; (b) Panel diagram of WSW-facing wall of a small geological trench excavated in the base of Subunit Vb showing complex interrelationships of sedimentary layers.

basal *c*. 55cm of Va is a granular (strongly granular base, moderately granular top) yellow-brown clay. Angular limestone clasts (varying between 2–10mm) are moderately common and generally flattened bedding parallel. This is followed by *c*. 105cm of massive uniform yellow-buff friable clay. The lower two-thirds of this unit have very dispersed coarse sand-grade material, whilst the top displays sub-horizontal (flattened) limestone clasts (cm scale). The thickness and massive nature of this horizon varies dramatically 1m either side of the studied part of the section.

The uppermost *c*. 60–70cm of Va is a massive medium reddish-brown calcareous clay-loam. The basal portions of this unit look finely granular; however, this is only very weakly displayed. Limestone clasts are generally absent and it is less lithified and more friable than the underlying parts of Va.

Unit IV
This horizon is between 110 and 118cm thick; its boundary with the top of Unit V is not sharp and is irregular in detail. Near its base, it is a medium greyish-brown calcareous clay (with a minor sand component) and it displays a weak, fine granular structure with a friable consistence. Limestone clasts are dispersed and not particularly common in the base; however, flattened sub-angular to rounded (cave wall) pebbles and cobbles become common towards the top of the unit along with fragments of bone and charcoal. Moving upwards through Unit IV the lithology shifts subtly to a friable calcareous sandy clay loam, with a moderate medium granular structure, and then on to a yellow-tan clay at the top.

Unit III
The transition between Unit IV and (overlying) III is predominantly marked by a change in the colour of the matrix. Unit III is generally darker compared to the top of Unit IV and is a medium tan-brown. The unit is approximately 60cm thick (thinning to *c*. 45cm in the north-west corner of the exposed platform) and is a (very) weakly granular friable calcareous clay. The colour is slightly darker than the top of Unit IV and is a medium tan-brown. Limestone clasts are reduced both in size and concentration in the unit; however, rare limestone fragments up to 18cm across were noted. Bone and charcoal are also present.

Unit II
This unit is quite variable in thickness. Close to the north-western wall of the chamber, where it was examined in detail, it is 101cm thick. It expands, however, to *c*. 130cm about 2m away as the unit appears to thicken towards the centre of the cave chamber. The top of Unit II is uneven and is largely responsible for this thickness variation. The base of the unit is flatter and the contact with underlying Unit III is sharp and conspicuous. Close to the north-western wall of the chamber this contact is stained reddish-brown.

The base of Unit II is a greyish/reddish brown sandy loam, becoming a paler greyish-brown sandy clay loam towards the top. Several other interesting trends are also noted in this unit. The structure grades from weakly granular in Unit III, to moderately granular in the base of Unit II, becoming granular towards the top of this unit. The base of Unit II is firm in consistence, becoming firm to friable towards the top. Most notably, however, Unit II becomes non-calcareous towards the top. Small, white carbonate granules are dispersed throughout, while disseminated brown and black charcoal fragments are generally confined to the upper 30cm. Pebble-grade limestone clasts (ranging in size from 0.5–5cm) are found throughout the unit and appear strongly decalcified and/or altered. Bone fragments are also common in this unit; however, they are commonly degraded and poorly preserved, particularly in the non-calcareous zones.

Unit I
This unit is highly variable both in terms of thickness and sedimentary composition and it caps the succession in Azokh 1. When it was initially examined on the Uppermost Platform (Fig. 3a), its thickness was calculated to be between 135–50cm. As excavation work has progressed and systematically cleared back these sediments, the thickness of Unit I is seen to reduce to between 80–90cm towards the interior of the cave.

Unit I is generally composed of a friable to loose reddish-brown non-calcareous clay loam. A moderate granular texture is displayed (becoming stronger towards the top) and limestone clast content is greatly diminished and strongly altered where present. The contact with the underlying unit is sharp: Unit I fills in the irregular topographic surface of Unit II. In one location, the basal portions of Unit I appeared to display a vague mm-scale lamination, which onlapped and draped Unit II.

A representative 'stratotype' section for Unit I is preserved in the rear of the chamber (Fig. 9; see also the top of Sediment Sequence 2 in Fig. 3), which demonstrates the two most conspicuous elements of this horizon. The first is a high level of disturbance, chiefly by mammalian burrowing, which has mixed much of the sediment. Several generations of large cut and backfilled burrows are evident in the unit; the most recent of which are still open. This has served to greatly complicate the details of the internal stratigraphy of this unit.

The second key feature of Unit I is the fumière (manure hearth) located near the top of the unit. This structure, which is at least 30–40cm thick, consists of a series of black, carbon-rich bands with greyish-white ash-rich interlayers. Soft, white carbonate granules are dispersed but common in the top 35cm of Unit I (Fig. 9). These are sometimes decalcified and may possibly be related to the heating effect of this large hearth structure on the surrounding sediment. There is

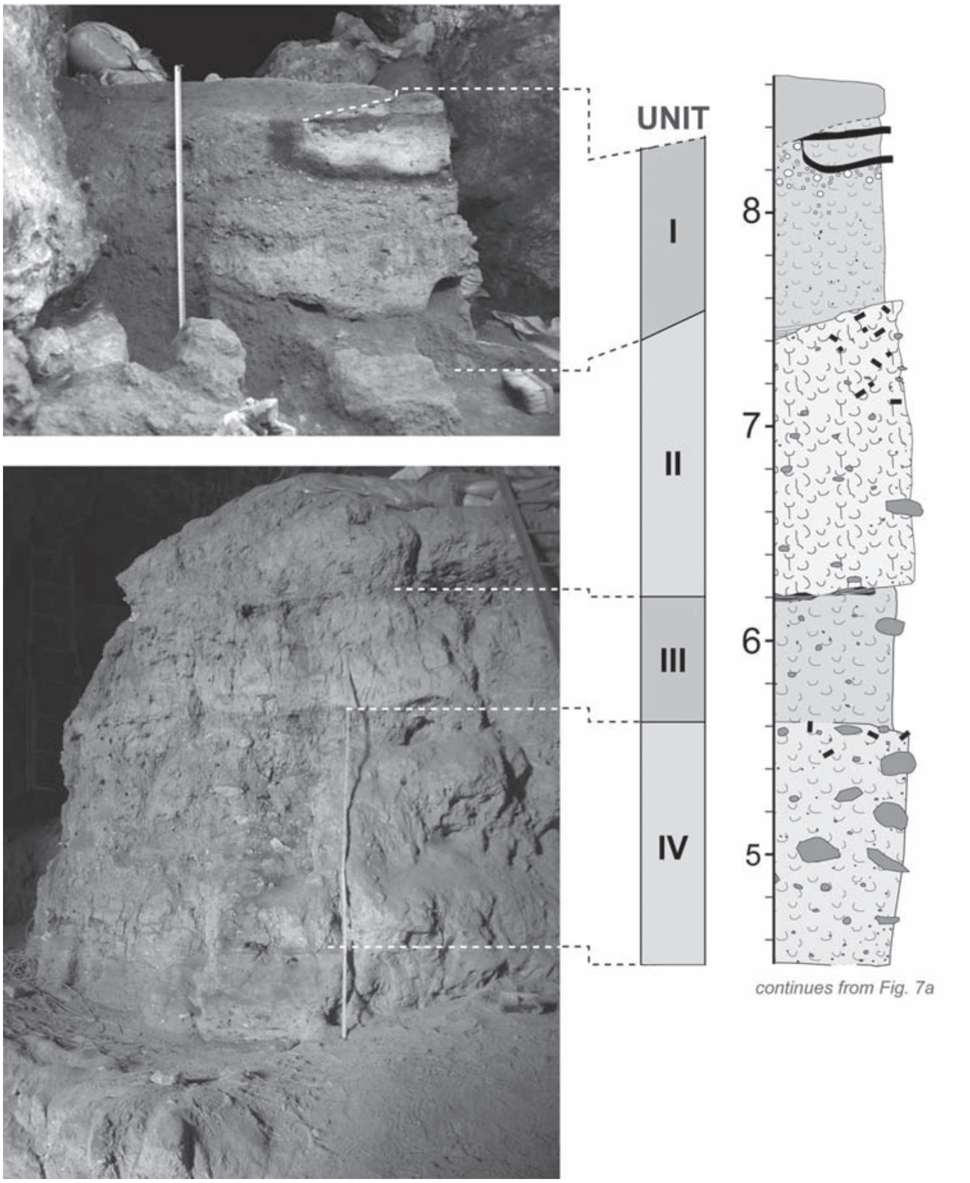

Fig. 8—Composite stratigraphic column for the top of Sediment Sequence 2 in Azokh 1. This log follows directly on from Fig. 7. The height of the wooden ruler in the lower photograph is 2m while in the upper photograph, the length of the tape is 88cm.

a particularly strong line of these white structures at about 25cm from the top of the unit.

Correlation of Sequence 1 and 2 in Azokh 1

As mentioned earlier, no *in-situ* sediment connection now remains between the two sediment sequences in Azokh 1. Using the floor of the cave as a datum, it would appear that the base of Subunit Vb in Sequence 2 is equivalent to the base of Subunit VIc or possibly even the upper portion of Unit VII in Sequence 1. Conglomeratic Subunit VIc is easily the most distinctive horizon in Azokh 1, yet it cannot be traced with any certainty away from the base of the pedestal. Traces of the conglomerate are seen adhering to the cave wall (in prominent notches developed between limestone beds) at ground level on either side of the chamber; however, they do not continue as far as the Middle Platform area.

The lenticular unit (bed (c) in Fig. 7b) in the base of Vb, with its erosive, channel style of bedding geometry and gravel content would seem a likely candidate for a direct lateral equivalent of Subunit VIc. Details of the sedimentology of the two units are not exactly in unison; however, it should be borne in mind that this could simply be a function of lateral facies variation.

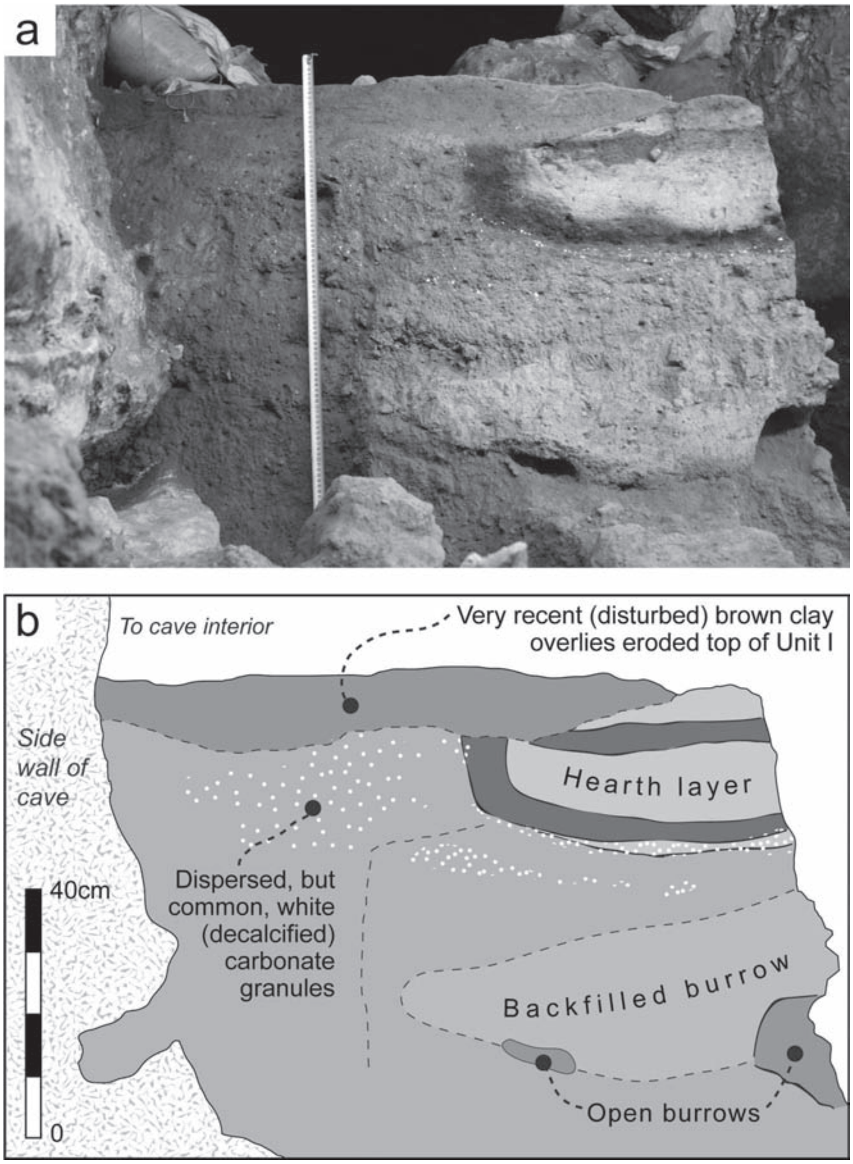

Fig 9—(a) Photograph of the top of Unit I exposed and cleaned during the 2007 field season; (b) Sketch interpretation of the photograph in (a) showing hearth layer (fumière), disturbance by burrows and erosive top to Unit I.

One final point to note is the increase in calcareousness in the units overlying VIc and horizon (c) in Subunit Vb. In Sequence 1, Subunit VIb is mildly calcareous, while VIa at the top of the preserved section is strongly calcareous. A similar transition is seen towards the top of Subunit Vb in Sequence 2 at the opposite end of the cave chamber.

Results and discussion

A total of between 11.2m and 11.8m of section (depending on how the two sequences are correlated) is preserved infilling Azokh 1. It is difficult to make a conclusive statement on the derivation and provenance of the sedimentary infill due to the limited extent of the remaining stratigraphy and its absence near the cave entrance. The general orientation and slope of the galleries appear to indicate water (and fine-sediment) flow from the interior of the cave system towards the valley outside. The resin-mounted sediment sample from the top of Unit VII contained plagioclase feldspar clasts, indicating an igneous source provided some input to the composition of the cave-filling sediment.

Conglomeratic Subunit VIc, located towards the top of Sediment Sequence 1, is distinct and clearly represents, at that point, a modification of sedimentation patterns within the cave passage. Units IX and VII below this level are predominantly fine-grained in character and *may* have been produced by fairly low-energy conditions. Subunit VIc, by contrast, is very coarse-grained and was produced by energetic water flowing through the cave passage. Not enough of this particular conglomeratic horizon is preserved to be able to make a definitive statement on palaeoflow direction based on clast imbrication. However, the fact that it cannot be readily identified in the base of the succession at the Middle Platform (Fig. 7; see discussion on correlation above and also Fig. 3 for general location) may suggest that this coarse clast-supported deposit was restricted to the vicinity of the chamber entrance and was thus produced by water flowing into the cave from the exterior.

Thus far in Sediment Sequence 1 only Unit VI (Subunits a–c) has proven to be fossiliferous. Bone material is first noted in the base of Subunit VIc. This is followed by a shift in the calcareous nature of the sediments and finally by a large rockfall (which caps the lower sequence). This may perhaps represent changing palaeoenvironments within the cave system, with a shift towards wetter or cooler conditions. Coarse, angular limestone debris in cave sediments has been interpreted by several workers (e.g. Laville *et al.* 1980; Courty and Vallverdu 2001) as evidence for frost action; however, Woodward and Goldberg (2001) caution that other geomorphological processes, such as seismic activity, dissolution and hydration shattering, may produce similar results.

The appearance of conglomeratic horizon VIc may thus, possibly, mark the point at which the cave chamber became more of an open system, encouraging animals and humans to venture inside. This is, however, difficult to prove conclusively due to the limited extent of the remaining section. In the past, stone tools were reported from the lower levels of Sediment Sequence 1 (Huseinov 1985); however, the validity of these finds has recently been strongly refuted (Doronichev 2008; Doronichev and Golovanova 2010).

In contrast, Sediment Sequence 2, which for the most part stratigraphically overlies Sequence 1, has proven to be abundantly fossiliferous. An extensive faunal list has been recorded from these units including cave bear (*Ursus spelaeus*); cervids; bovids; horses; large and small canids (*Canis* and *Vulpex*); land tortoises; lagomorphs; rodents; birds and amphibians (see Fernández-Jalvo *et al.* 2010 and references therein). Medium and large felids (*Lynx* and *Panthera*) and suids (*Sus*) have been recorded in Unit II, rhinoceros in Bed IV, while hippopotamus and hyena (*Crocuta*) have been recovered from Unit V. At the present time one of the largest bat populations in the Caucasus reside in the inner reaches of the cave system and it is therefore unsurprising that their remains dominate the micro-mammal fraction from many of the units.

Numerous stone tools have been recovered from Sequence 2. The majority of these are manufactured from locally sourced chert. Implements recovered from Unit V appear Acheulean in character; however, these are not conclusive (Fernández-Jalvo *et al.* 2010). Interestingly, rare obsidian tools were recovered from several horizons, including Units V and II. Obsidian is not readily obtainable in the region immediately surrounding the cave and this suggests transport, or perhaps even exchange, from further afield. Stone tools recovered from Units II and III are believed to be Mousterian, and more specifically, Bed II assigned to Levallois technology, thus the transition from Lower to Middle Palaeolithic potentially occurs between the top of Unit V and through Unit IV. Unfortunately, Unit IV has not been properly excavated to date, so no stone tools have been found thus far.

In addition to the stone tools, butchery marks on a large number of the finds, mainly cave bear, and charcoal spread throughout the sequence, attest to the presence of humans in the cave from at least Unit V onwards (Fernández-Jalvo *et al.* 2010). Unit V is significant in this respect as it was from the general area of this horizon that the partial mandible of *Homo heidelbergensis* was originally recovered (Huseinov 1985; Kasimova 2001). Unfortunately, the exact level of this find remains unclear. Kasimova (2001) noted two conflicting reports on the matter. The first, by Gadzhiev and Huseinov, produced in 1970, stated the specimen was discovered in the third horizon of the fifth layer, while an alternative report by Huseinov (the initial discoverer of the jaw fragment) stated that it was recovered in the fifth horizon of the fifth layer. As mentioned earlier, Lioubine (2002) also noted the inadequacies of the original stratigraphic control of finds and the lack of proper documentation of lateral facies variation moving from the outside towards the inside of the chamber, mainly based on sediment colour. According to Lioubine (2002, 23), in his review of previous reports on the stratigraphy, Unit V apparently thinned dramatically from 5 to 2m; however, more precise details are not available. Lioubine (2002) points out that with the current 'stepped back' appearance of the excavation (see Fig. 3a), important palaeoclimatic information contained in deposits located close to the cave entrance is severely compromised, as the same units are never adequately represented moving back towards the cave interior.

According to Simms (1994) three main types of concentrative mechanism can be recognised for vertebrate fossil accumulations in caves:

I. *Biotic autochthonous*—the animal in question lived and died within the environment of the cave. This grouping can be subdivided into organisms that spend their entire life cycle (*Troglobious cavernicoles*) and those who spend only a portion of their life cycles (*Troglophilic cavernicoles*) within the cave system. The latter sub-grouping includes animals that may enter a cave to forage for food or to find shelter or to roost.

II. *Biotic allochthonous*—the animal remains were transported into the cave by another organism (typically a predator).

III. *Abiotic allochthonous*—an abiotic process (such as flooding or gravity collapse) introduces the animal remains into the cave environment.

There is no direct evidence to indicate an *abiotic allochthonous* accumulation mechanism for the fossil fauna from Sediment Sequence 2 in Azokh 1. This is perhaps unsurprising given the limited extent of the remaining stratigraphy. The fauna, thus, clearly falls between the *biotic autochthonous* and *biotic allochthonous* categories—the essential question being were the various animal groups sheltering or living temporarily within the cave or were the remains introduced by human or non-human predators? This important question is still being investigated by the wider research team involved with the Azokh project; however, some preliminary comments may be made here:

1. Bat remains are an extremely diverse and common component of the micro-mammal fauna (Fernández-Jalvo *et al.* 2010). The cave system was, and currently is, an important roosting site for this particular group and they clearly represent a *troglophilic cavernicole* sub-category of Simm's (1994) *biotic autochthonous* grouping.
2. *Ursus spelaeus* (cave bear) are the most abundant macro-mammal component (Fernández-Jalvo *et al.* 2010). These were probably using the cave for both shelter and also as hibernacula and thus could be considered as *troglophilic cavrnicoles*.
3. There is evidence of human occupation from almost all units in Sediment Sequence 2 in the form of stone tools, cut-marks on animal bones and charcoals. This is interpreted by Fernández-Jalvo *et al.* (2010) as representing several occupation levels or perhaps intermittent visits to exploit animals living in the cave. The human factor in helping to produce a *biotic allochthonous* accumulation of vertebrate material can, thus, not be discounted.

Several radiometric methods have been employed by the current team to try to better constrain the age of the succession. In the case of Unit V, this is important given the significance of the hominid jaw fragment recovered from it. These methods have provided mixed results and are reported by Fernández-Jalvo *et al.* (2004, 2010). Uranium series dating suggests an age of *c*. 200ka, whilst racemisation (D/LAsp) has indicated an age closer to 300ka. Electron Spin Resonance (ESR) dating has provided a figure of 293 +/- 23ka (Rainer Grün pers. comm. 2010). All of these age estimates confirm an age of at least Middle Pleistocene for Unit V.

Estimation of the age of the sediment fill below Unit V (essentially Units IX to VII in Sequence 1) is more problematic. It could be that Sequence 1 records a smooth, continuous and unbroken succession from the time of the infilling of the basal trench, up into the infill of the main chamber above. Conglomeratic Subunit VIc, however, represents increased strength of water flow, at this point in the chamber, and it is possible that it eroded some parts of the underlying succession, introducing a time gap of unknown duration in the sequence.

Above Unit V in Sequence 2 there appears to be, more or less, a continuous infill of sediment until the top of Unit II. Units III and II have yielded evidence of human occupation in the form of stone tools, cut marks and charcoal. ESR dating of bone from the area of the contact between the top of Unit V and the base of Unit IV produced an age of 208±27ka. Radiocarbon dating of material from Bed II was unsuccessful and it has been suggested that this is due to age of the unit exceeding the radiocarbon range of 60ka.

The bulk of the section in Sequence 2 (Subunit Va up to the base of Unit II) is calcareous in nature. Towards the top of Unit II an important shift in the chemistry of the sequence occurs as the sediments become non-calcareous and, as mentioned earlier, the quality of preservation of bone material tends to deteriorate dramatically. Preliminary X-ray diffraction (XRD) work conducted on several units in Azokh 1, including Unit II, have shown the presence of tinsleyite (K and Al-rich hydrated phosphate), a diagenetic mineral phase in the sediment, in bones and sediment. Recent work

(Magela da Costa and Rúbia Ribeiro 2001; Marincea *et al.* 2002) has shown this mineral to be formed as a result of the presence of bat guano. This relationship is not exclusive; however, it is entirely possible that the non-calcareous top of Unit II may represent an elevation in the amount of bat guano being deposited at this point in the cave's history and that this may have helped to elevate the acidity of the sediment, resulting in the noticeably poor preservation of many bones.

The transition between Units II and I appears disconformable. The highly irregular top of Unit II, which is effectively draped by Unit I, would suggest possible modification and erosion of the top surface of the unit prior to the resumption of sedimentation. This is further supported by an apparent time-gap between the two units. Unit I contains a relatively undisturbed fumière (it is partially eroded across the top, see Fig. 9). Charcoal from this horizon has provided a radiocarbon age of 157±26 years BP (Fernández-Jalvo *et al.* 2010). It is difficult to assess the age of the highly disturbed and reworked sediments, which directly underlie the fumière. A Russian coin dating from around the mid-1960s was found in sediment above this hearth layer in Unit I in 2006. This appeared to have been moved downwards by burrowing activities of mammals. On balance, it seems likely that Unit I is largely Holocene in age, albeit intensively reworked and affected by bioturbation, and that the actual Quaternary–Holocene boundary transition is not fully represented in the section.

Conclusions

Azokh 1 is part of a larger karstic cave network developed in Mesozoic limestone and has a (bed-rock) floor developed on two levels. In the central section of the passage, it is between 11–11.5m from the roof; however, this surface slopes down rapidly to a lower level moving towards the present entrance to the cave (Fig. 3a). This drop in floor level generated greater accommodation space for sediment and may also support the contention that water flow was directed towards the WSW during the dissolution phase of passage formation.

Between 11.2m and 11.8m of sediment subsequently infilled Azokh 1 from, at least, Middle Pleistocene times towards the present. Much of this sediment has been removed by previous excavation teams; however, enough remains to make a basic assessment of the stratigraphy. The nature of the sediment infill is generally very fine-grained (clay and silt grade), suggestive of either quiet patterns of water flow, perhaps related to ponding associated with flood events further inside the cave system, or possible wind blown derivation. The latter scenario is unlikely for the sediments located in the rear of the passage while it is difficult to test for sediments close to the cave entrance as they have been removed. Wind-blown sediments should be uniformly fine-grained and well-sorted and this is evidently not apparent in Sediment Sequence 1.

The base of the succession exposed in Sediment Sequence 1 (Units IX to VII) appears to record a reasonably continuous and progressive infill of this lower level in the passage. The age of these sediments is uncertain at present. Unit VI, which lies directly above these units, contains a distinctive conglomeratic subunit in its base, indicating a marked increase in the strength of water flow through Azokh 1. It is possible that erosion of some of the section occurred at this point. Above the conglomerate horizon, the sediments return to being very fine-grained in character. Elevated levels of limestone and chert clasts in some of these horizons (such as towards the top of Unit IV) may indicate wetter or colder periods in the history of the cave.

The upper portion of the succession (Sediment Sequence 2) is now available for study only in the rear of Azokh 1. The sediments become calcareous from the middle of Unit V until the lower portions of Unit II. The contacts between Units V, IV, III and II all appear reasonably conformable, indicating progressive infill of the passage during this time interval. Detailed excavation has demonstrated a disconformable relationship between the top of Units II and I at the top of the succession.

Fossils have thus far been observed only in the upper part of the sediment infill (from Unit VI onwards). This *may* be due to the opening of the cave system at this point; however, given the limited remaining extent of strata underlying this particular level, this is not easy to demonstrate conclusively. A diverse macro- and micro-mammalian fossil assemblage, including specimens of cave bear (*Ursus spelaeus*), has been recovered from Units V to II. Bed V is dated at around 300ka and in the past, it produced a specimen of *Homo heidelbergensis*. Human activity in the cave is clearly evident throughout this upper sequence in the form of charcoals, stone tools and butchery marks on bones.

Given the geographic position of Azokh Cave in the Southern Caucasus, on a strategically important route-way between the African and Eurasian continents, and its fossiliferous sedimentary succession spanning a critically important interval of time in human prehistory, its significance as a site for archaeological and palaeoanthropological research cannot be underestimated. Continued future excavation work at Azokh will hopefully reveal important details about the *H. heidelbergensis–H. neanderthalensis* transition and migratory patterns followed by both humans and animals during this time period.

Acknowledgements

We would like to thank the authorities in Nagorno-Karabagh for enthusiastically supporting this work and granting permission to excavate at the site. The staff at the Artsakh State Museum of History and Country Study are thanked for providing advice and support. Dr Seyran Hayrabetyan is thanked for his help with some of the infrastructural difficulties encountered during excavations. The team are indebted to a great many individuals and groups from Azokh village who supply much needed ground support to the excavation work year after year. In particular, John Murray and Patricio Domínguez-Alonso would like to make a special note of thanks to Masis Ohanyan and Zorig Asryan who very ably assisted with the survey of the cave interior. John Murray would like to acknowledge support from the National University of Ireland, Galway, Triennial Travel Grant. We are grateful to a number of institutions for funding and academic support provided to this work—the Museo Nacional de Ciencias Naturales, and The Spanish Ministry of Science that partially financed through research projects (BTE2000-1309, BTE2003-01552; BTE 2007-66231) as well as the Armenian Institute, British Academy and the Harold Hyam Wingate and Wenner-Gren Foundations. We thank Armenian General Benevolent Union (London Trust) for the continued financial support it has provided over the years. We are also very grateful for financial support that has been provided by three anonymous donors. Mike Simms is thanked for providing several useful and thought-provoking comments during review.

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