Comparing Lower and Middle Palaeolithic lithic procurement behaviors within the Hrazdan basin of central Armenia

Ellery Frahm[1,*], Caderyn Owen Jones[1], Michael Corolla[2], Keith N. Wilkinson[3], Jenni E. Sherriff[4], Boris Gasparyan[5], and Daniel S. Adler[6]

[1] Council on Archaeological Studies, Department of Anthropology, Yale University, United States

[2] Yale University Archaeomagnetism Laboratory, Department of Anthropology, Yale University, United States

[3] Department of Archaeology, Anthropology and Geography, University of Winchester, United Kingdom

[4] Centre for Quaternary Research, Department of Geography, Royal Holloway, University of London, United Kingdom

[5] Institute of Archaeology and Ethnography, National Academy of Sciences of the Republic of Armenia, Republic of Armenia

[6] Old World Archaeology Program, Department of Anthropology, University of Connecticut, United States

* corresponding author. E-mail address: ellery.frahm@yale.edu

Abstract:

The Hrazdan River valley in Armenia contains Lower, Middle, and Upper Paleolithic archaeological sites and offers access to the Gutansar Volcanic Complex, a large and important source of obsidian. The sites' occupants primarily acquired lithic material from this obsidian source, which is manifested throughout the local landscape, but its obsidian exposures, produced during a single eruptive phase, exhibit the same geochemical signature. This situation inspired the development of rock magnetic characterization as a means to recognize obsidian from different spots across the volcanic complex (i.e., intra-source, not inter-source, characterization). This intra-source approach was first applied to the Middle Palaeolithic site of Lusakert Cave 1, where the data revealed that the occupants collected obsidian throughout the river valley, rather than a preferred outcrop, quarrying area, or secondary deposit. Such a finding implied that the toolstone procurement spatially coincided with the valley and was embedded in subsistence activities. In this new study, the same approach to intra-source magnetic characterization is applied to the Lower Palaeolithic site of Nor Geghi 1 – specifically, to obsidian debris dated between 440 and 335 millennia ago. The magnetic measurements show that, like at Lusakert Cave 1, toolstone acquisition occurred within the valley. If, as we propose, obsidian procurement reflects the spatial distribution of subsistence activities, it attests that archaic hominins at both sites and in both periods were able to effectively exploit a resource-rich riparian ecosystem. Consequently, this study provides an example of behaviors shared by Middle and Lower Palaeolithic

hominins whereby, placed within the same landscape, their resource exploitation behaviors appear indistinguishable.

Keywords:
Palaeolithic archaeology; Lithic raw material procurement; Provisioning strategies; Armenian Highlands; Obsidian sourcing; Rock magnetic characterization

1. Introduction

Advances in geochronological, genetic, and skeletal morphological studies have pushed back the emergence – or, at least, an increase in the prevalence – of Neanderthal biological traits before Marine Isotope Stage (MIS) 8, circa 300 to 243 thousand years ago (300–243 ka), a period that has been regarded by some scholars as a cutoff point between *Homo heidelbergensis* and Neanderthals (Papagianni and Morse, 2013). Consider, for example, the hominin fossils at the Middle Pleistocene (MP) sites of Fontana Ranuccio and Visogliano in central and northeastern Italy, respectively. The former site dates to ~450 ka (Ascenzi and Segre, 1996; Muttoni et al., 2009), and the fossil-bearing stratum of the latter site dates to ~480–440 ka (Falguères et al., 2008, 2010) – that is, both sites fall into MIS 12 (~478–424 ka). Using geometric morphometrics with high-resolution X-ray tomography, Zanolli et al. (2018) show that the dental remains at these sites exhibit a Neanderthal-like structural signal. Another example is Sima de los Huesos (SH), which lies within the Sierra de Atapuerca karstic cave system in Spain. The fossil-rich stratum of this site has been dated to 434 ± 30 ka (Arsuaga et al., 2014), and it contains > 6500 hominin fossils, including 17 skulls. Morphological analyses by Arsuaga et al. (2014) attest to derived Neanderthal features in the face and cranial vault. Others (e.g., Hublin, 2009; Stringer, 2012) have also seen the SH hominins as early members of the Neanderthal clade. Such interpretations have been supported by nuclear DNA analysis of two SH individuals, which Meyer et al. (2016:506) conclude "were early Neanderthals or closely related to the ancestors of Neanderthals" after their divergence from a common ancestor with the Denisovans. Therefore, even if the MP hominins from these three sites should not be regarded as Neanderthals *sensu stricto*, they share biological apomorphies with Neanderthals, attesting to the fact that particular elements of Neanderthal physiology existed in Europe prior to MIS 8 (> 300 ka).

Recognizing behavioral commonalities between such "pre-Neanderthals" (Dean et al., 1998) and later "classic" Neanderthals has been challenging. For example, not only is the interpretation of SH as a case of deliberate interment with symbolic behavior controversial (e.g., Arsuaga et al., 1997; Bocquet-Appel and Arsuaga, 1999; Bermúdez de Castro et al., 2004; Carbonell and Mosquera, 2006;

Sala et al., 2015), but also the issue of intentional Neanderthal burials has yet to be laid to rest (e.g., Sandgathe et al., 2011; Walker et al., 2012; Rendu et al., 2014, 2016; Dibble et al., 2015; Zilhão, 2016; Goldberg et al., 2017). In another example, due to exceptional organic preservation at Schöningen in northern Germany, recent work has overturned previous interpretations of the Middle Pleistocene hominin behaviors preserved in this lignite mine (Conard et al., 2015). The famed "Horse Butchery Site" at Schöningen, circa 340–300 ka (Richter and Krbetschek, 2015), was viewed by its excavator, H. Thieme, as a massive, organized hunting event and butchering spot with evidence of ritual, namely deliberate abandonment of eight wooden throwing spears along the shore of a lake (Thieme, 2007; Musil, 2007). Scientific studies, though, have yielded alternative interpretations for this site. Isotopic signatures of the horses' teeth, which reveal varied diets and habitats, suggest that the remains reflect multiple small events, not a singular slaughter (Julien et al., 2015; Kuitems et al., 2015; Rivals et al., 2015). Areas of reddened sediments, once seen as evidence of hearths, have been recognized as rich in iron compounds deposited as the lake receded (Stahlschmidt et al., 2015a). Sedimentological and paleoenvironmental studies also reveal that this site has always been underwater, so the spears were more likely lost than ritually put there (Stahlschmidt et al., 2015b; Urban et al., 2015). In light of the interpretive challenges for MP sites such as SH and Schöningen, it should be evident that scientific analyses – in particular, those derived from the earth sciences – have been essential for recognizing behavioral clues in the material culture of Neanderthals and their predecessors.

Another challenge for comparing archaic humans' behaviors is transcontinental variation in geographic settings. For example, the Schöningen spears might be compared to and contrasted with the Clacton spear (Warren, 1911; Allington-Jones, 2015), found in southeastern England in 1911 (e.g., the former spears are made from spruce and pine wood, whereas the latter is yew). Their find sites, though, are ~700 km apart. The potential for geographic differences in Palaeolithic behaviors – due to variation in environmental and/or social contexts – have been implicated in a number of debates, including Neanderthals' control (or lack thereof) of fire (Dibble et al., 2018 in Western Europe vs. Brittingham et al., 2019 in the Armenian Highlands). There are, of course, clusters of sites that span different eras, thereby permitting a diachronic perspective within a shared locale. For example, the aforementioned SH can be compared to other sites in the Atapuerca complex (e.g., Galería, Sima del Elefante), that is, in the same geological setting. For instance, the only lithic artifact from SH (~0.43 Ma) – an Acheulean (Mode 2) hand axe made from exotic red quartzite – can be better understood in contrast with the Mode 1 lithics (flakes and debitage, n=23), made from locally available chert (< 2 km), found at the nearby site of Sima del Elefante (~1.2–1.1 Ma; Carbonell et al., 2008).

The Hrazdan River valley in central Armenia is another such region, where a cluster of sites spans the Lower (e.g., Hatis 1, Ghazryan, 1986; Nor Geghi 1, Adler et al., 2014), Middle (i.e., Lusakert Cave 1, Adler et al., 2012; Alapars 1, Malinsky-Buller et al., forthcoming), and Upper Palaeolithic (e.g., Solak 1, Adler et al., unpublished; see also Gasparyan and Arimura, 2014 and Sherriff et al., 2019 for overviews). In addition, these sites all lie a short distance (≤ 6 km) from one of the largest and most important obsidian sources in the Armenian Highlands: the Gutansar Volcanic Complex (GVC). While obsidian-bearing lava flows and domes rarely exceed 10 km^2 (Walker, 1973; Hughes and Smith, 1993), the area of the GVC is at least seven times greater (although parts are covered by later lavas and alluvium). These circumstances mean that hominins primarily acquired their toolstone from a sizable obsidian source that is manifested in various spots on the landscape but that has a uniform geochemical signature due to its singular volcanic origin. This, in turn, led to the development of rock magnetic characterization to identify obsidian from different parts of the GVC (see Section 3; Frahm and Feinberg, 2013; Frahm et al., 2014). When this novel approach was applied for the first time at the Middle Palaeolithic site of Lusakert Cave 1 (LKT1), Frahm et al. (2016) showed that, during a cold phase that is provisionally dated to MIS 4 (~71–57 ka), the occupants collected toolstone within the adjacent valley, rather than from a preferred outcrop or quarry, presumably in the course of day-to-day subsistence activities. This suggests toolstone acquisition was embedded in foraging practices as one component in the efficient exploitation of a resource-rich riparian ecosystem.

Here we apply the same approach to magnetic characterization to obsidian artifacts from the Lower Palaeolithic open-air site of Nor Geghi 1 (NG1), located only ~3 km south of LKT1 (Fig. 1). These artifacts, all small debris, were excavated from sediments that date between 440 and 335 ka. Our magnetic measurements and statistical tests show the same pattern as was observed at LKT1, indicating that the NG1 occupants also principally collected obsidian along the MP river valley and floodplain. Such an outcome implies that these hominins also practiced embedded procurement, as anticipated within a toolstone-rich landscape. If, as we propose, obsidian procurement reflects the spatial distribution of their subsistence activities, it attests that the NG1 occupants were as capable as the LKT1 occupants in exploiting the river valley. Consequently, based on these datasets, there is no evidence to indicate that these Lower and Middle Palaeolithic hominins had markedly different practices with respect to toolstone acquisition and subsistence in the Hrazdan basin. While separated by roughly three hundred millennia, these archaic hominins apparently had the capacities needed to behave in similar ways when placed within the same general landscape.

2. Background: NG1 and the GVC

Both NG1 and the GVC have previously been described and discussed in the literature (e.g., Adler et al., 2012, 2014; Frahm et al., 2014, 2016; Sherriff et al., 2019), so our principal focus in the following sections is providing information most relevant to the study at hand. Readers interested in additional details are forwarded to these publications.

2.1. Lower Palaeolithic NG1

NG1 (Fig. 2a; 40.34679° N, 44.59706° E) is exposed in the Hrazdan valley wall over a length of 135 m. During an attempt to build a road down to the river, a bulldozer uncovered a section with fine-grained alluvium that contained paleosols and in situ obsidian artifacts. The fluvio-lacustrine sediments are bounded above and below by lava flows – specifically, basaltic trachyandesites – from a nearby Quaternary volcano (Adler et al., 2014; Sherriff et al., 2019). The sediments were deposited through a series of alluvial and damming episodes in what was once a fluctuating system of low-energy floodplains and lakes, that was eventually capped by the final lava flow in the vicinity of this site (Sherriff et al., 2019). The capping ("Lava 1") and underlying ("Lava 7") flows have been dated using the $^{40}Ar/^{39}Ar$ technique: 197 ± 7 and 441 ± 6 ka, respectively (Adler et al., 2014). Additionally, sanidine grains extracted from volcanic tephra in the topmost sedimentary unit (Unit 1) have been dated by $^{40}Ar/^{39}Ar$ to 308 ± 3 ka. These dates reveal that a stratigraphic unconformity exists between the top of the sedimentary sequence and the capping flow. Consequently, all of the artifacts contained within the sedimentary sequence date between ~310 and ~440 ka, thereby representing hominin behaviors between MIS 11 (~424–374 ka) and MIS 9 (~337–300 ka).

NG1 was found in 2008 and excavated until 2017 by the Hrazdan Gorge Palaeolithic Project (HGPP; Adler et al., 2012, 2014). Excavations between 2008 and 2013 focused on the northern half of the site, where obsidian artifacts attributed to MIS 9e (335–325 ka) exhibit the earliest evidence of the transition from Mode 2 (Acheulian) to Mode 3 (Levallois) lithic technology (Adler et al., 2014). Levallois cores and flakes occur not only with Acheulian bifaces but also with bifaces that have been recycled into Levallois cores – in the same stratigraphic layer. The findings are documented in detail by Adler et al. (2014). Archaeological, geochronological, and sedimentological analyses are ongoing for the site's southern half, excavated from 2015 to 2017, which documents earlier sediments and occupations, and is dominated by biface technology with an absence of Levallois or other hierarchical core methods. Precise dates for this half of the site are forthcoming. Given the capping and underlying lava flows, the southern section must, however, fall between ~310 and ~440 ka. Because sediments in the southern section underlie those to the north, they must be older than ~335 ka. Therefore, the archaeological material contained therein is roughly contemporaneous with the MP sites discussed in the Introduction. This is relevant given that the obsidian artifacts for this study come from the dry-sieved sediment samples excavated from the southern section of NG1.

2.2. The Hrazdan valley and GVC

Since the publication of Frahm et al. (2016), the Hrazdan valley and its associated geological features have been re-mapped by the Pleistocene Archaeology, Geochronology, and Environment of the Southern Caucasus (PAGES) Project. This includes an updated map of the GVC and its obsidian-bearing features (Fig. 3). NG1 lies on the western side of the river valley, and the highest point of the GVC – a scoria cone associated with the principal volcanic edifice – is visible from the site, as shown in Fig 2b. To the north, the Hrazdan River originates from Lake Sevan, and it drains into the Araxes River to the south. Sherriff et al. (2019) summarize the findings of the PAGES Project, including the reconstructed processes that led to the formation of this deeply incised valley.

The obsidian-bearing features of the GVC are (i) the extensive Gutansar flow, which exhibits both extrusive and near-surface debris-flow aspects, (ii) the Alapars lava dome, and (iii) the Fontan (also transliterated as "Fantan") dome. Despite the different names, obsidian from these features is geochemically indistinguishable (Frahm et al., 2014). In addition, the trace-element composition of obsidian in, for example, the northernmost parts of the GVC is not measurably distinct from that in its southernmost parts, despite being almost 13 km apart. Furthermore, obsidian found throughout the GVC appears to have formed contemporaneously; however, an accurate date remains unclear as a result of inconsistencies between fission-track and radiometric (i.e., $^{40}K/^{40}Ar$, $^{40}Ar/^{39}Ar$) methods (Karapetian, 1972; Komarov et al., 1972; Badalian et al., 2001; Arutynunyan et al., 2007; Lebedev et al., 2013; Adler et al., 2014). Lebedev et al. (2013) obtained to two $^{40}K/^{40}Ar$ dates from GVC obsidian specimens: 480 ± 50 ka and 1.2 ± 0.5 Ma. Given the sizable uncertainty of the latter date, the former – ~480 ka – is thought to be the more reasonable possibility for its true age.

For most obsidian-bearing flows, domes, and dikes, glassy obsidian is buried beneath either a pumice carapace, its weathered matrix, or subsequent lava flows. As a result, obsidian typically is accessible only where it protrudes toward the surface or where outcrops have been exposed due to erosion, slope processes, faulting, tectonics, and emplacement forces. In this regard, the GVC is like other obsidian sources. Its obsidian is accessible where exposed by natural (e.g., gully erosion) and anthropogenic (e.g., road, railway, and pipeline cuts) processes. For example, outcrops occur along a ~1.4-km stretch of the Hrazdan valley (Fig. 4a) and in various locations across the GVC. A series of modern quarries (Fig. 4b) reveal the extent of this obsidian source, much of which is hidden under fields and meadows. Downstream sedimentary strata exposed in the valley escarpment occasionally contain obsidian nodules in secondary alluvial deposits (Fig. 4c); however, these nodules can be so heavily damaged and cracked that they shatter in one's hands. Throughout the complex, outcrops of high-quality obsidian are as close as the nearest gully. No doubt these exposures differed in terms of their precise placement during the MP. Where we can observe and sample obsidian outcrops today is certainly not identical to exposures during the past. The same geomorphological processes, though, would most likely have led to outcrops, for example, along the paleo-Hrazdan River similar to those along the modern river valley. Today we can observe that the magnetic properties of GVC obsidian exhibit continuous ranges across the complex (Frahm et al., 2014), but whether now or in the past, geomorphology and hominin behavior combine (i.e., collecting obsidian from where it is exposed) to create clusters in the magnetic data, as we discuss in the next section.

3. Magnetic characterization of obsidian

It should be emphasized that we employ magnetic characterization in a way quite different than conventional geochemical obsidian sourcing (i.e., inter-source characterization) and from other researchers who have sought to use rock magnetism as a direct substitute for geochemical obsidian sourcing (see Table 1 in Frahm and Feinberg, 2013). The methods of geochemical obsidian sourcing – sometimes called "trace-element fingerprinting" – seek to attribute artifacts to a specific volcanic flow based on their elemental compositions. Since the foundational research of Cann and Renfrew (1964), hundreds of studies (see Kuzman et al., 2020) have shown that artifacts can be matched to flows using one of several analytical techniques, including X-ray fluorescence (XRF).

Magnetic analyses, in contrast, measure the properties of microscopic minerals that occur in all obsidian. Even the glassiest obsidian has sub-millimeter mineral inclusions, especially magnetite (Fe_3O_4) grains that are responsible for its black color. These magnetite grains, which exhibit magnetic properties, act as sensitive recorders of localized eruptive and emplacement conditions that varied throughout an obsidian flow (Frahm and Feinberg, 2013; Frahm et al., 2014). Obsidian experiences variations in temperature, viscosity, oxidation, deformation, and so on as it cools throughout a lava flow. These spatially variable circumstances during eruption and emplacement, as a result, influence the amounts, size distributions, shapes, mineralogies, and arrangements of the microscopic (titano-) magnetite grains within the obsidian and, consequently, the magnetic properties.

Variability in the magnetite assemblage of a given obsidian-bearing flow was detrimental to studies that sought to magnetically distinguish different sources and attribute artifacts to them. For example, McDougall et al. (1983) showed that three magnetic properties could differentiate the two obsidian sources on the island of Melos, Sta Nychia and Dhemenegaki, but the latter overlapped with the other Aegean obsidian sources, rendering magnetic characterization of little archaeological use. Similar overlaps in subsequent studies (e.g., Urrutia-Fucugauchi, 1999 in Mexico; Vásquez et al., 2001 in the Andes; Zanella et al., 2012 in the Mediterranean) attest that magnetic properties of obsidian flows are considerably more variable than their glass compositions (see Frahm and Feinberg, 2013). As a result, attempts to source obsidian artifacts to particular volcanoes by magnetic means were, at best, ambiguous. Consequently, magnetic sourcing never saw widespread use.

Our approach takes advantage of the spatially variable magnetic minerals within an obsidian flow and uses it to learn more about artifacts' origins within that specific source. Frahm and Feinberg (2013) observed and demonstrated the magnetic properties of obsidian are similar on small spatial scales (e.g., particular outcrops) and exhibit greater variation as the scale increases (e.g., the flank of the volcano, a transect across an obsidian-bearing flow). This phenomenon occurs for all magnetic parameters that have been tested (Frahm and Feinberg, 2013; Frahm et al., 2014). Simply put, the magnetic properties of obsidian exhibit a uniformity on the scale of centimeters and meters that is absent, for example, on the scale of kilometers. The emplacement and cooling conditions would, we expect, be largely continuous through a lava flow, so the magnetic properties of the obsidian would likely also exhibit continuous ranges. It is, therefore, only the combination of hominin behavior and landscape (i.e., acquiring obsidian where it has been exposed at the surface due to erosion, faulting, or other forces) that together result in clusters within artifacts' magnetic data.

It is worthwhile stressing that outcrop-to-outcrop magnetic variability is not necessarily so distinct that it will always be possible to match an artifact to an exact location in a lava flow. Different portions of an obsidian-bearing lava flow could have experienced conditions that created a similar net result for the magnetic properties. It would take lifetimes to establish whether a set of magnetic properties occurs exclusively in a particular cubic meter of obsidian for a flow that Karapetian et al. (2001) estimates to be about 5 km^3 (at least 5×10^{10} specimens according to our protocols in Frahm et al., 2014). Consequently, our focus here is the way in which behavioral patterns on the landscape can be reflected within a particular assemblage of obsidian artifacts.

4. Procurement models

Here we consider six hypotheses (based on the five in Frahm et al., 2016) that describe how NG1 inhabitants may have acquired local toolstone: GVC obsidian. Each of the hypotheses relates to the locations where procurement behaviors occurred. Binford (1979) proposed that procurement can be described as *direct*, involving special-purpose trips to a source, or *embedded*, occurring in the context of subsistence and related activities. In the real world, these procurement strategies are not binary but instead exist on a continuum. For example, as hunter-gatherers' mobility strategies vary in response to the season, environment, or other local conditions, it may be that an occasional direct foray to acquire toolstone occurred alongside embedded strategies. We assume that visitors to NG1, arriving at the site from multiple directions, exhibited behavioral flexibility such that their dominant strategy for toolstone procurement at or near this site might not have been used elsewhere, shifting as they moved through their territory ranges and/or as the seasons changed.

The series of hypothesized strategies is schematically represented in Figure 5. As described in the following sections, obsidian specimens were collected throughout the GVC in ways that were intended to replicate these hypotheses regarding toolstone procurement. One result is that the GVC has been magnetically characterized much more thoroughly than any other obsidian source in the world (n = 603 subsamples), so we have confidence in the sample sizes used to create the following models. Interested readers can find additional details in Frahm et al. (2016).

4.1. Hypothesis #1

Obsidian procurement occurred on the same geographic scale as extended foraging activities carried out from the site, assumed to be ~10 km, resulting in acquisition from various obsidian outcrops and exposures scattered across the extensive Gutansar flow.

This hypothesis is consistent with the NG1 inhabitants as foragers (*sensu* Binford, 1980) who practiced high logistical and low residential mobility. Ethnographic and energetic studies of modern humans commonly report maximum daily foraging radii of ~6–12 km (Kelly, 1995; Binford, 2001), but such distances can vary greatly by ecological context. This hypothesis ostensibly correlates with the exploitation of diverse resources as it suggests a large foraging area. This model was simulated by sampling numerous obsidian outcrops and exposures across the Gutansar flow as much as 9 km from NG1, that is, inside a foraging radius of 10 km from the site. The greatest coverage of the flow was sought for this model, so the sampled exposures include not only erosional features (e.g., gullies) and mass wasting locations (i.e., slope failure) but also road cuts and modern quarries.

4.2. Hypothesis #2

Obsidian procurement occurred within the palaeo-Hrazdan River valley, which resulted in the collection of obsidian from numerous outcrops and exposures along the river valley.

This hypothesis is consistent with procurement during subsistence activities carried out in the river valley, where water as well as diverse faunal and floral resources would have been readily available. It is also compatible, though, with forays through the valley specifically to collect obsidian when necessary. Like Hypothesis #1, it is consistent with foragers who moved residential camps to resource-rich areas, as we might expect given the location of NG1. To simulate obsidian acquisition while tracking prey through the palaeo-Hrazdan valley, cattle were followed in the modern valley for three days. Obsidian was collected whenever outcrops or other exposures were encountered. Thus, the specimens were collected from varied spots throughout the valley, not just a specific locus. If the NG1 inhabitants principally collected obsidian when required for tools to, for example, butcher and process prey moving through this valley, their procurement patterns were likely similar. It is worth noting that this was the supported hypothesis for LKT1 (Frahm et al., 2016).

4.3. Hypothesis #3

Obsidian procurement was targeted and focused on a preferred outcrop or outcrops.

In contrast to Binford's ethnographic research, there are accounts of toolstone procurement from a preferred source, sometimes (but not always) related to the material qualities (Gould, 1978; Gould and Saggers, 1985). Small task-focused groups were sent on short-term excursions to obtain toolstone, closer to Binford's (1980) definition of collectors. Embedded procurement, however, can still be consistent with this hypothesis: a certain outcrop might have been targeted, but subsistence activities in the vicinity could be planned to coincide with the need to collect toolstone. Preferential collection from specific outcrops was simulated by sampling two obsidian exposures just outside the valley but within a foraging radius of 5 km: one is 4 km NE of NG1 (Outcrop A), and the other is 3 km NE (Outcrop B). A small area (~1–3 m^2) was sampled at each. It should be stressed that the aim here is to not determine whether or not these exact outcrops were used but instead to recognize general patterns in magnetic data due to preferentially exploiting specific outcrops.

4.4. Hypothesis #4

Obsidian procurement was focused on conspicuous landmarks on the landscape, such as lava domes.

This hypothesis is consistent with Molyneaux's (2002) proposal that conspicuous features, such as Devils Tower and Obsidian Cliff in the American West, played important roles in wayfinding and cognitive mapping, affecting the movements of people and toolstone. Specifically, he suggested that "Devils Tower exhibits a *centripetal* effect, as it drew" in travelers while "Obsidian Cliff exhibits a powerful *centrifugal* effect, as people carried its raw material across vast regions of central North America" (Molyneaux, 2002:136). This idea led Frahm (2012) to offer that a conspicuous obsidian-bearing landscape feature could simultaneously draw in travelers (centripetal effect) and serve as a source of toolstone that is distributed by visitors (centrifugal effect). This model was simulated by sampling two obsidian-bearing GVC lava domes: Fontan and Alapars. The Fontan dome, as it appears today, is ~100 m across and ~20 m tall, but it has a complex history regarding its MP formation and modern exposure through quarrying. Fontan was clearly an attractive location in the past given that, in 2011, the HGPP discovered a Middle Palaeolithic site, dated to MIS 5, immediately adjacent to this dome (Malinsky-Buller et al., forthcoming). Alapars is wider (~1 km) and taller (~80 m), and lithic artifacts were also encountered while sampling this dome.

4.5. Hypothesis #5

Obsidian procurement was targeted and involved "industrial" quarrying (e.g., digging a series of pits in a given area to access obsidian where it occurs at or near the surface).

Away from the valley, there are locations scattered across the GVC where sizable obsidian-bearing facies reach the surface (or nearly do so). Such locations would provide an opportunity for toolstone quarrying akin to that reported in the Levant (e.g., Barkai et al., 2006; Barkai and Gopher, 2009; Gopher and Barkai, 2014). The Mount Pua quarry complex, for example, consists of hundreds of pits across ~90 ha, following a subsurface chert layer (Gopher and Barkai, 2014). This hypothesis is consistent with the occurrence of specialized quarrying sites, at which large-scale extraction and initial working transpired prior to its transport. This model was simulated using an anthropogenic exposure of near-surface obsidian in a modern quarry, which processed the pumiceous material for concrete production. An immense amount of obsidian reaches the surface over a sizable area (~62 ha) in this location, ~5 km E of NG1. Specimens were collected along an 80-m exposure (Fig. 4b) to mimic a series of extraction pits. Like Hypothesis #3, our goal is not to determine if this exact spot was exploited by the NG1 inhabitants. Instead, the focus of this model is establishing basic patterns in magnetic properties due to exploiting obsidian from a circumscribed area.

4.6. Hypothesis #6

Obsidian procurement involved exploiting cobbles in alluvial deposits along the river.

Although there are abundant opportunities to collect obsidian from outcrops and exposures across the GVC, it is also accessible in alluvial deposits in the valley, where small cobbles have been transported and rounded by the palaeo-Hrazdan River (but these same forces have also introduced fractures that limit the cobbles' utility as toolstone). This hypothesis is consistent with exploitation of chert cobbles from secondary deposits at Palaeolithic sites in France (e.g., La Chapelle-aux-Saints, Demars, 1990) and elsewhere (e.g., Egypt; Vermeersch et al. 1990, 1995). Procurement from an alluvial deposit of GVC obsidian along the palaeo-Hrazdan was simulated by sampling the only such deposit that we have located (Fig. 4c), a short distance upstream from NG1.

5. Materials and methods

This section discusses the collection, selection, and preparation of NG1 artifacts for the study at hand as well as the methods of their geochemical and magnetic analyses.

5.1. Excavation methods at NG1

Adler et al. (2014) report on the HGPP excavation methods at NG1 but focus on the work in the northern part of the site between 2008 and 2013. The same methods were followed between 2014 and 2017 in the southern part. Larger obsidian artifacts (≥ 25 mm); stratigraphic boundaries; and sediment samples for sieving as well as the chronological and geoarchaeological research were recorded in three dimensions using two Leica total stations. The excavated sediment was recorded spatially as samples ~15–20 liters in volume. All of the sediment samples were dry-sieved through a 0.5-cm mesh and picked in order to recover smaller lithic artifacts, which were sorted into three size classes: maximum diameters of ≥ 25 mm, 24–15 mm, and ≤ 14 mm.

5.2. Geochemical analyses by pXRF

A sample of 500 obsidian fragments were drawn from the small debris (< 25 mm) recovered from the excavated sediments. To determine the volcanic sources of these fragments, each one was analyzed using pXRF in the Yale University Archaeological Laboratories. Specifically, we used an Olympus Vanta VMR instrument, which is equipped with a Rh anode, a 4-W X-ray tube, and a large-area (40 mm^2) silicon drift detector with an excellent spectral resolution ($\lesssim$ 140 eV) at high X-ray count rates ($\gtrsim$ 100,000 X-ray counts/sec). When the instrument is operated in the "GeoChem" mode, its tube current and voltage change in combination with built-in beam filters as a means to better fluoresce the heavier and lighter parts of the periodic table of elements. Each measurement took 25 seconds: 15 seconds for the heavier elements at 40 kV and ~70 μA, and then just moments later, 10 seconds for the lighter elements at 10 kV and ~90 μA. Each obsidian fragment was analyzed twice with repositioning between measurements to avoid any morphological effects.

The data were corrected using Olympus' fundamental parameters (FP) implementation as a means to adjust for various phenomena that affect the relationships between raw X-ray intensities and elemental concentrations (e.g., fluorescent and absorption edges, mass attenuation coefficients, Coster-Kronig transition probabilities, Rayleigh and Compton cross sections). Accuracy was checked with three well-characterized obsidian specimens: GBOR01 obsidian (Little Glass Buttes, Oregon; a reference material from the University of Missouri's Research Reactor), RGM-1/2 (Glass Mountain, California; a standard from the United States Geological Survey), and NIST 278 (Newberry Crater, Oregon; a standard from the United States National Institute of Standards and Technology). Table 1 summarizes previously published analyses for these obsidians (see Frahm and Brody, 2019) and lists our pXRF measurements, which agree with the means from the literature.

Small lithic size classes are often excluded from pXRF-based obsidian sourcing (e.g., Golitko, 2011; Sheppard et al., 2011; Goodale et al., 2012; Kellett et al., 2013; Galipaud et al., 2014; Coffman and Rasic, 2015; Millhauser et al., 2015) because they are often regarded as "too small" for XRF (e.g., Eerkens et al., 2002, 2007; Davis et al., 2011; Shackley, 2011, 2012; Ferguson, 2012; Freund, 2014; Escola et al., 2016). Here, however, we follow protocols that we have published (Frahm, 2016) and applied (Frahm et al., 2016): the use of ratios between calibrated, corrected, and quantitative "mid-Z" elemental data to cancel out systematic error due to artifacts' small sizes (i.e., obsidian artifacts as small as a few millimeters in diameter). In particular, Frahm et al. (2016) used a scatterplot of Sr/Rb vs. Zr/Rb (i.e., Sr vs. Zr normalized to Rb) for source identifications of LKT1 obsidian debris, and we follow the same procedure in this study for the analyzed artifacts from NG1.

5.3. Magnetic analyses by VSM

From the sourced obsidian fragments, a sample of 100 specimens was randomly drawn and screened for magnetic testing using three criteria. First, any specimens for magnetic analysis had to originate from the GVC rather than another obsidian source. Second, for reasons that are detailed by Frahm et al. (2014:169–170), an abundance of hematite (Fe_2O_3) in a specimen can confound efforts to magnetically characterize magnetite (Fe_3O_4) grains within the obsidian. Our solution has been to exclude hematite-rich specimens from the datasets. Previously we have employed a hysteresis loop shape parameter (σ_{hys}) to remove hematite-rich obsidian (i.e., positive values indicate hematite-rich obsidian, whereas negative values indicate magnetite-rich obsidian). A faster procedure is simply to exclude specimens that exhibit the red color of hematite. Third, the specimens had to be a suitable size. A specimen had to be small enough to fit into the Princeton Measurements MicroMag vibrating sample magnetometer (VSM; Fig. 6) but large enough to be measured quickly (i.e., larger specimens have more magnetic material and, hence, can be measured more rapidly). Specimens ~8–14 mm in maximum dimension are ideal. Applying these selection criteria resulted in 61 artifacts, which were cleaned with tap water in an ultrasonic cleaner and air-dried. Mass was recorded with high precision (to the nearest 0.1 mg) to normalize magnetic measurements to an artifact's mass.

The four measured magnetic properties, which are known as *hysteresis parameters*, primarily reflect innate characteristics of the obsidian artifacts' magnetite inclusions (e.g., their sizes, shapes, compositions, amounts, orientations). Hysteresis parameters are found by measuring a specimen's induced magnetization when a strong magnetic field is applied and varies in strength (up to 1.5 T in this instance). Our measurements were taken at room temperature with a Princeton Measurements VSM. A hysteresis loop and a backfield curve were acquired for each artifact along two orthogonal axes, often the longest and shortest appropriate for the VSM. The four hysteresis parameters were measured (Fig. 7): saturation magnetization (M_s), saturation remanence (M_r), coercivity (B_c), and coercivity of remanence (B_{cr}). As discussed by Frahm et al. (2014:168), M_s, which is measured when the applied magnetic field is at its strongest, reflects the concentration of magnetic material within a particular specimen. M_r, which is measured after the applied magnetic field has been removed, is the highest possible permanent magnetization. It primarily reflects the magnetic material concentration and mean grain size, but factors such as grain alignments and interactions can also affect it. B_c is the applied field strength when a specimen's induced magnetization returns to zero, and it is inversely correlated to grain size. B_{cr} is the field strength needed to remagnetize half of a specimen's magnetic minerals so that M_r equals zero, and it too is inversely related to mean grain size. Ratios between the parameters are also useful. The remanence (M_r/M_s) and coercivity ratios (B_{cr}/B_c) reflect grain size: smaller magnetic grains tend to yield higher M_r/M_s and lower B_{cr}/B_c values.

The two orthogonal measurements for each artifact were intended to minimize the effects of anisotropy (i.e., directional effects if any flow bands exist in the obsidian). These two measurements were averaged in order to calculate bulk mean values for each artifact. It is also worth noting that a M_r/M_s ratio of 0.5 is, in theory, the maximum value for randomly oriented, uniaxial, non-interacting magnetic grains. Greater M_r/M_s ratios would imply the presence of strong, non-random alignments of mineral inclusions, including the aligned minerals that compose flow bands. None of the artifacts' ratios have values more than 0.25, which indicates that, for the artifacts in question, flow banding is negligible. Three parameters (M_s, M_r, B_c) were measured using a hysteresis loop (~4 min), while the fourth (B_{cr}) was measured with a backfield curve (~11 min). Including optimizing the VSM between each artifact and its reorientation, the total instrument time was ~40 hours.

5.4. Other types of magnetic measurements

Our earlier studies (e.g., Frahm and Feinberg, 2013; Frahm et al., 2014) measured low-field magnetic susceptibility (χ) using a KLY-2 KappaBridge susceptibility bridge and MAGNON variable-frequency susceptibility meter. For a relatively simple assemblage of magnetic minerals, χ functions as a proxy for the amount of magnetic material in a specimen. Given that M_s can also serve as such a proxy, we concluded that measuring χ was not necessary in light of the added time and equipment requirements. Our pilot work also included natural remanent magnetization (NRM), measured using a 2G Enterprises 755 cryogenic, superconducting rock magnetometer inside a shielded room with a background magnetic field < 100 nT (Frahm and Feinberg, 2013). In obsidian, NRM is mainly due to the thermal remanent magnetization (TRM), which was acquired as it cooled. This, too, was deemed unnecessary for the purposes of intra-source characterization. Lastly, small geological specimens of obsidian were measured using a Quantum Designs MPMS (magnetic property measurement system) cryogenic susceptometer (Frahm, unpublished). These measurements, which take several hours per specimen, allow magnetic mineral identifications using low-temperature crystallographic transitions (e.g., the Verwey transition at ~110 K in magnetite) and particle size characterizations, particularly for ultra-fine superparamagnetic grains. Hysteresis parameters, however, can provide some of this information (Fig. 8) without the considerable time investment required.

5.5. Comparative GVC magnetic data

The NG1 artifacts' magnetic measurements were compared to the GVC datasets discussed by Frahm et al. (2016:81–83). In short, obsidian specimens were collected in ways intended to replicate different procurement patterns, as discussed in Section 4. For example, to mimic collection across a large portion of the Gutansar flow, the specimens and their data reflect the broadest coverage of the full lava flow. To simulate obsidian acquisition from a preferred outcrop location, 20 specimens from two individual outcrops were collected and measured. Specimens were also collected from a larger obsidian exposure (which served as a proxy for a quarrying area) and from two lava domes (Fontan and Alapars). To mimic obsidian procurement through the valley while hunting~ fauna or gathering flora, we followed grazing cattle along the river for three days. Specimens were collected whenever obsidian outcrops or exposures were happened upon, meaning that multiple outcrops and exposures are represented in this population and its corresponding dataset. Lastly, to simulate collection from an alluvial deposit along the paleo-Hrazdan River, obsidian cobbles were sampled from a lag deposit located near NG1. In summary, all of these geological specimens were collected from throughout this volcanic complex specifically with magnetic characterization in mind.

6. Geochemical and magnetic results

Figure 9 is a scatterplot of Sr/Rb vs. Zr/Rb for the 500 NG1 artifacts analyzed using pXRF as well as the corresponding data from likely geological sources, previously collected and published by

Frahm et al. (2016). The elemental data show that all but four of these obsidian fragments (*n* = 496, 99.2%) originated from the GVC. One came from Kamakar (one of the three Tsaghkunyats sources, ~25 km N of NG1), while three geochemically match Hatis (~12 km SE of NG1).

The magnetic data for NG1 artifacts were compared to eight geological datasets: exposures encountered along the Hrazdan River valley, a secondary alluvial deposit, two outcrops, a quarrying area, the Fontan and Alapars lava domes, and the Gutansar flow. We employed quadratic canonical discriminant function analysis (JMP software from SAS) using the four hysteresis parameters (M_s, M_r, B_c, and B_{cr}) and the two ratios (M_r/M_s and B_{cr}/B_c) as variables and using five datasets (the outcrops, lava domes, and quarry) as the discrete training groups. Figure 10 plots the outcomes from applying the first two functions to the artifacts and all eight geological datasets. These first two discriminant functions account for 69% and 22%, respectively, of the variability, for a total of 91%. A simple visual examination of the scatterplots, graphing these first two discriminant functions, reveals the greatest affinity in magntic measurements between the NG1 artifacts and Hrazdan valley specimens, but the similitude between these two populations can be shown more rigorously.

Figs. 11 and 12 are box-percentile plots (Esty and Banfield, 2003) for the first and second discriminant functions, respectively. Such plots – a variant of the traditional box-and-whisker plot – illustrate the distribution of the magnetic data. These shapes extend to the maxima and minima, and their width at any given point is proportional to the percentile. The median is demarcated by a solid line at the widest point, while the first and third quartiles are denoted by dashed lines that are half the width of the median line. These plots again reveal the affinity between the NG1 artifacts and the Hrazdan valley specimens. Using one-way ANOVA testing (Table 2), especially for the first function, establishes that the artifacts and Hrazdan specimens exhibit the greatest similarity, followed by the specimens collected from across the entire Gutansar lava flow. This similarity is expected given that the obsidian outcrops along the Hrazdan valley derive from the Gutansar flow.

7. Interpretation and discussion

The obsidian sources identified among the small debris at LKT1 and NG1 (Fig. 1) are highly similar. First, in terms of the sample sizes of artifacts that we tested by pXRF, the difference between the six non-GVC obsidian artifacts identified at LKT1 and the four non-GVC obsidian artifacts at NG1 is not statistically significantly different (two-tailed z-score test, $p = 0.688$). Second, the non-GVC obsidian artifacts at both sites originate from Hatis volcano and one or two of the Tsaghkunyats sources. The three Tsaghkunyats sources are geochemically distinct (Fig. 9) lava domes at a relatively high elevation (~2400 m) within the same mountain range. Consequently, as reported by Badalyan et al. (2004), secondary deposits, sometimes containing obsidian intermingled from more than one dome, can be found at lower elevations (~2000 m). For example, the so-called Hankavan secondary deposit (located near a village of the same name) contains obsidian cobbles carried down from both the Damlik and Ttvakar domes. Given the existence of such secondary deposits, it is not necessarily behaviorally meaningful which Tsaghkunyats source occurs within an assemblage. For this reason, Badalyan et al. (2004) argue that the Tsaghkunyats obsidian sources might best be combined when making archaeological comparisons. Following their line of reasoning, one cannot conclude that the sources identified in the LKT1 and NG1 small debris are meaningfully different.

Our statistical analyses (Figs. 10 to 12 and Table 2) reveal that the tested NG1 artifacts have magnetic properties most similar to the geological obsidian specimens we collected throughout the Hrazdan river valley. That is, obsidian was not acquired from only one outcrop, based on the spread of the magnetic data. Instead, the dispersion of our magnetic measurements establish that multiple outcrops and exposures were exploited throughout the river valley by the NG1 occupants. This is the same outcome as at LKT1: collection throughout the valley (Frahm et al., 2016). We interpret this result as support for Hypothesis #2: toolstone procurement principally occurred in the river valley, resulting in obsidian that derived from various outcrops and exposures along the ancient river and floodplain. As described in Section 4.2, the comparative sample utilized to test this hypothesis was collected over the course of three days while tracking "prey" (i.e., grazing cattle) through the modern river valley. We expect that, if the NG1 inhabitants largely acquired obsidian while moving through the palaeo-Hrazdan valley, then bounded by Lower Pleistocene volcanic deposits from the GVC and Mt. Arailer (see Sherriff et al., 2019, especially their Figure 12), the procurement patterns likely were generally similar to our own movements. Hence, like at LKT1 (Frahm et al., 2016), we argue that the obsidian procurement taskscape (Ingold, 1993) coincided with the palaeo-Hrazdan valley. This result is also consistent with expectations that, within a landscape rich in toolstone resources, embedded procurement will be the dominant strategy (Binford, 1979; Duke and Steele, 2010). The procurement of obsidian throughout the ancient valley, we propose, likely also reflects the spatial distribution of subsistence activities. This, in turn, implies that adequate food existed in the immediate surroundings and that the NG1 occupants were able to exploit this rich and diverse ecosystem.

Our geochemical (inter-source) and magnetic (intra-source) results are complementary. In particular, like at LKT1, obsidian from Hatis is rare among the NG1 small debris – only three artifacts out of 500 (0.6%). Hatis, however, is not only ~12 km from NG1 but also immediately southeast of the GVC (Fig. 3). Nevertheless, hominins did not routinely transport obsidian from this volcano to NG1. The GVC obsidian outcrops most distant from this site are ~9 km away, and our magnetic data suggest that these and other outcrops outside the palaeo-Hrazdan valley were rarely transported to this location. Consequently, the proximity of Hatis volcano but the scarcity of its obsidian reinforce our interpretation of the magnetic data as indicative of valley-centric procurement.

Differences in the depositional and taphonomic effects on the LKT1 and NG1 lithics must be considered as a potential complication in directly comparing their results. From LKT1, Frahm et al. (2016) analyzed the small debris from three sediment samples in one of the most lithic-rich layers, Unit 6, with thin ash spreads (remnants of combustion, probably hearth features) and horizontally-bedded silty-clay sediments. The ash lenses of hearths indicate little post-depositional disturbance, but nevertheless, the obsidian debris in these sediment samples still reflects a time-averaged signal. In contrast, the lithic artifacts at NG1 appear to reflect repeated hominin activities conducted on the fairly stable surfaces of the palaeo-Hrazdan floodplain. Consequently, for both LKT1 and NG1, the magnetically measured artifacts reflect time-averaged signals, rather than individual events, and, in turn, represent behavioral variations over, perhaps, multiple generations.

It has been proposed that, at least in southwestern France, that chert outcrop quarrying was rare due to the difficulties of extricating chert from veins or nodule-bearing limestone and that, as a result, chert was primarily acquired from alluvial deposits along streams and rivers (Demars, 1982; Bordes, 1984; Turq, 1988, 1989). In contrast to chert, obsidian is more brittle and less hard (5–6 on Moh's hardness scale compared to 6.5–7 for chert). Hence, not only is obsidian easier to extract from outcrops, but also it is much more readily damaged by battering and frost action as cobbles found in secondary deposits. Observations at the studied alluvial deposit (Fig. 4c), the only MP deposit that we have located along the course of the paleo-Hrazdan River, attests that such cobbles were unlikely toolstone resources during the Lower Palaeolithic. Even if the small cobbles (i.e., the very largest are ~10 cm, but most fall in the ~1–5 cm range) were suited to some forms of lithic reduction, they still tend to be too damaged by frost and/or bashing to function reliably as toolstone. This observation is consistent with the magnetic data, on the basis of which we hold that alluvial deposits were not the principal sources of obsidian for the visitors to NG1. One could argue that exploiting obsidian from multiple alluvial deposits, each of which drew obsidian from different suites of outcrops along the river, may yield a distribution of magnetic values not easily distinguished from the valley-collected dataset. To produce such a pattern, alluvial deposits would need to either (1) lie in varied locations throughout the valley to capture obsidian from different outcrops or (2) exist well downstream in a location where obsidian from different outcrops could be well mixed (although cobbles further down the valley should be even smaller and more damaged). In the former situation, exploiting obsidian from various alluvial deposits yield behaviors similar to those for Hypothesis #2. That is, toolstone collection from numerous obsidian exposures in the valley – whether primary outcrops or alluvial deposits – can be similar not only magnetically but also behaviorally.

The prior findings from LKT1 (Frahm et al., 2016) and our new results from NG1 document an apparent continuity in obsidian procurement behaviors, spanning from ~440–335 ka at the latter site to ~71–57 ka at the former. That is, there is no evidence between these studies to suggest that Lower and Middle Palaeolithic hominins had considerably different practices related to toolstone acquisition within the paleo-Hrazdan river basin. During these two periods at least, there is no clear relationship between procurement behaviors and (potentially) different hominin populations. This outcome might be, in part, a consequence of the GVC landscape, across which excellent obsidian is virtually ubiquitous. Hominins on such a landscape could carry out subsistence activities largely free of concerns regarding where and when they would next find toolstone to restock.

8. Conclusions

Recent studies are increasingly pushing back the appearance of Neanderthal biological traits prior to MIS 8 (~300–243 ka) to as far back as MIS 12 (~478–424 ka). That is, particular elements of their *physiology* existed in Europe before MIS 8. Identifying *behavioral* commonalities between such pre-Neanderthals and later Neanderthals has been more challenging, in part due to the geographic differences among sites distributed across vast distances. Serendipitously, the Hrazdan River valley in central Armenia has a cluster of Lower, Middle, and Upper Paleolithic sites as well as access to the GVC, one of the largest and most important obsidian sources within the Armenian Highlands. The occupants of these sites primarily acquired toolstone from the GVC, which is manifested in numerous locations scattered across the landscape, but these obsidian exposures have a uniform geochemical signature. This situation inspired the development of magnetic characterization to identify obsidian from different GVC locations (Frahm and Feinberg, 2013; Frahm et al., 2014).

This magnetic approach was applied for the first time to the Middle Palaeolithic site of LKT1, specifically to small obsidian debris from a stratum provisionally dated to MIS 4 (~71–57 ka; Frahm et al., 2016). Frahm et al. (2016) demonstrate it was not the case that one or two specific obsidian outcrops were preferred by the LKT1 occupants. Nor did they collect their obsidian from quarrying areas, from locations across the entire volcanic complex, or from alluvial deposits. The data instead support a hypothesis that the occupants principally collected obsidian from outcrops and exposures scattered through the Hrazdan valley in its Late Pleistocene form, reflecting the scale of their day-to-day subsistence activities. Their taskscape for toolstone procurement apparently coincides with the valley. This result suggests that toolstone acquisition was embedded within foraging practices as a component in the efficient exploitation of a resource-rich river valley ecosystem.

In the present study, the same approach to magnetic characterization is applied to the Lower Palaeolithic site of NG1, in particular to similar small debris from sediments that date between ~440 and ~335 ka. Statistical analyses reveal that these artifacts, like those from LKT1, exhibit properties most similar to the obsidian specimens we collected through the modern Hrazdan River valley. We interpret this as support for Hypothesis #2: toolstone procurement principally occurred within the MP valley and its floodplain, resulting in obsidian from a variety of primary outcrops and exposures. Consequently, like at LKT1, the taskscape of obsidian procurement coincided with the valley as it existed at the time. Such an outcome is consistent with the expectation that, within such a toolstone-rich landscape, embedded procurement is the dominant strategy for replenishing stocks of lithic raw materials. If, as we propose, the procurement of obsidian throughout the MP valley and floodplain reflects the spatial distribution of subsistence activities, it attests that the NG1 occupants were similarly capable of exploiting this resource-rich riparian ecosystem.

Additionally, for both LKT1 and NG1, the small debris was analyzed by pXRF. At both sites, the debris not from the GVC geochemically matched either Hatis volcano or one of the Tsaghkunyats obsidian sources, meaning that the geographic origins of these artifacts are not distinct. There are no far-flung obsidian sources represented exclusively at one site or the other. In addition, the fractions of debris from the non-GVC sources are not statistically different. Consequently, based on this lithic class, movements over the wider landscape are also indistinguishable.

Considering the results of our chemical and magnetic analysis of obsidian debris from NG1 in light of the same datasets from LKT1 (Frahm et al., 2016), there is no evidence to suggest that Lower and Middle Palaeolithic hominins had markedly different practices related to toolstone acquisition within the paleo-Hrazdan basin. That is, there appears to be no clear relationship between hominin populations and procurement behaviors. This might not be true in all contexts. Indeed, such a result might be a product of the GVC landscape, where hominins could carry out subsistence activities free of concerns regarding where and when they could locate new toolstone. Our findings, though, imply that the hominin occupants of the sites, separated by approximately 300 millennia, had the requisite capacities to efficiently procure toolstone in the context of other foraging activities. Thus, we provide a new example of behaviors shared among Middle and Lower Palaeolithic hominins, such that, when placed in the same general landscape, their practices were indistinguishable. The result is crucial for studies that seek, for example, to model population dynamics or explain population replacements in terms of archaic humans' disparate capacities to exploit the landscape.

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Figure captions

Fig. 1. Map of Armenia showing obsidian sources (circles), select source complexes (dashed lines), and the Lower Palaeolithic site of Nor Geghi 1 (black square).

Fig. 2. (a) Photograph of NG1, looking toward the west from the eastern side of the Hrazdan valley, and the associated geomorphological features. (b) Photograph of the Hrazdan valley, looking north-east from NG1, showing the visibility of the Gutansar cone. Photographs by the authors.

Fig. 3. Redrawn version of the geological map for the Gutansar volcanic complex from Sherriff et al. (2019), largely based on that of Karapetian and Karapetian (1971).

Fig. 4. (a) Example of a GVC obsidian outcrop along the Hrazdan valley. (b) A 80-m exposure of near-surface obsidian in a pumice/perlite quarry, which we sampled to replicate extraction pits following a specific geological facies. Our friend and colleague, the late Sergei Karapetian (Chief Researcher in the Volcanology Department of Armenia's Institute of Geological Sciences) is pictured. (c) An alluvial obsidian deposit along the Hrazdan River valley, upstream from NG1. The Ingalls handpick is 31 cm in length. Photographs by the authors.

Fig. 5. Sketches of the Hrazdan valley and the GVC to illustrate the different procurement strategies that we hypothesize the NG1 occupants might have used. The relative dimensions of the floodplain, valley, and other features are exaggerated and not to scale. The straight lines that connect the site to the obsidian exposures are neither literal paths nor intended to imply direct excursions.

Fig. 6. (a) The vibrating sample magnetometer (VSM) used in this study. (b) A close-up photograph of an obsidian artifact held by a plastic sample holder between the two electromagnetic pole pieces and field sensors. Photographs by the authors.

Fig. 7. A generic hysteresis loop after processing (i.e., after the paramagnetic contribution from the glass has been subtracted), illustrating the relationships among the applied magnetic field (B); the specimen's magnetic moment (M) in response; and the measurement of remanence (M_r), saturation magnetization (M_s), coercivity (B_c), and coercivity of remanence (B_{cr}).

Fig. 8. (a) Day plot (B_{cr}/B_c vs. M_r/M_s) of the NG1 obsidian artifacts with magnetic domain boundaries (dotted blue lines) and magnetite mixing curves (solid green lines) from Dunlop (2002). All artifacts fall in the pseudo-single domain (PSD) region of the plot, not the single domain (SD) or multi-domain (MD) regions. Magnetite grains exhibit PSD behavior in the 0.1 to 20 μm size range. (b) NG1 artifact data (B_c vs. M_r/M_s) with the compositional lines for magnetite (TM0) and titanomagnetite (TM60) based on calculations by Wang and Van der Voo (2004).

Fig. 9. A scatterplot of Sr/Rb vs. Zr/Rb (i.e., Sr vs. Zr normalized to Rb) for the geological obsidian specimens and the NG1 small debris in this study. This scatterplot is directly comparable to Figure 7a in Frahm et al. (2016:84).

Fig. 10. Scatterplots of the first and second discriminant functions applied to the magnetic data for the different obsidian sampling areas.

Fig. 11. A box-percentile plot (Esty and Banfield, 2003) of the first discriminant function applied to the magnetic data for the different obsidian sampling areas.

Fig. 12. A box-percentile plot (Esty and Banfield, 2003) of the second discriminant function applied to the magnetic data for the different obsidian sampling areas.

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Figure 1

Aghvorik
Tsaghkunyats sources
Damlik
Ttvakar
Kamakar
Mets Arteni
Pokr Arteni
LKT1
NG1
Gutansar
Hatis
Lake Sevan
Spitakasar
Geghasar
Khorapor
Satanakar
Sevkar
Bazenk
Obsidian source not identified in small debris
Obsidian source identified in NG1 small debris
Obsidian source identified in LKT1 small debris
50 km

Figure 2

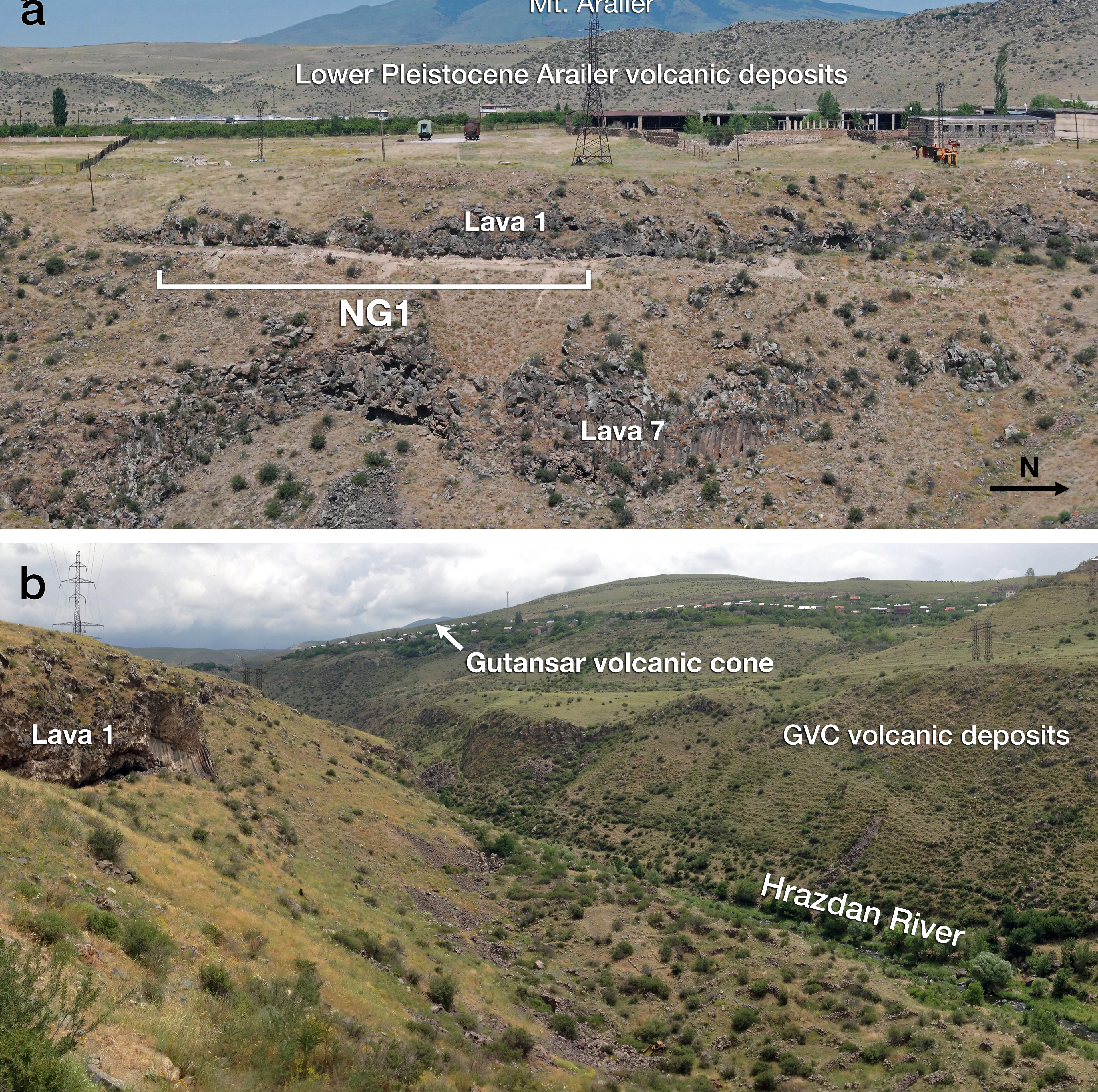
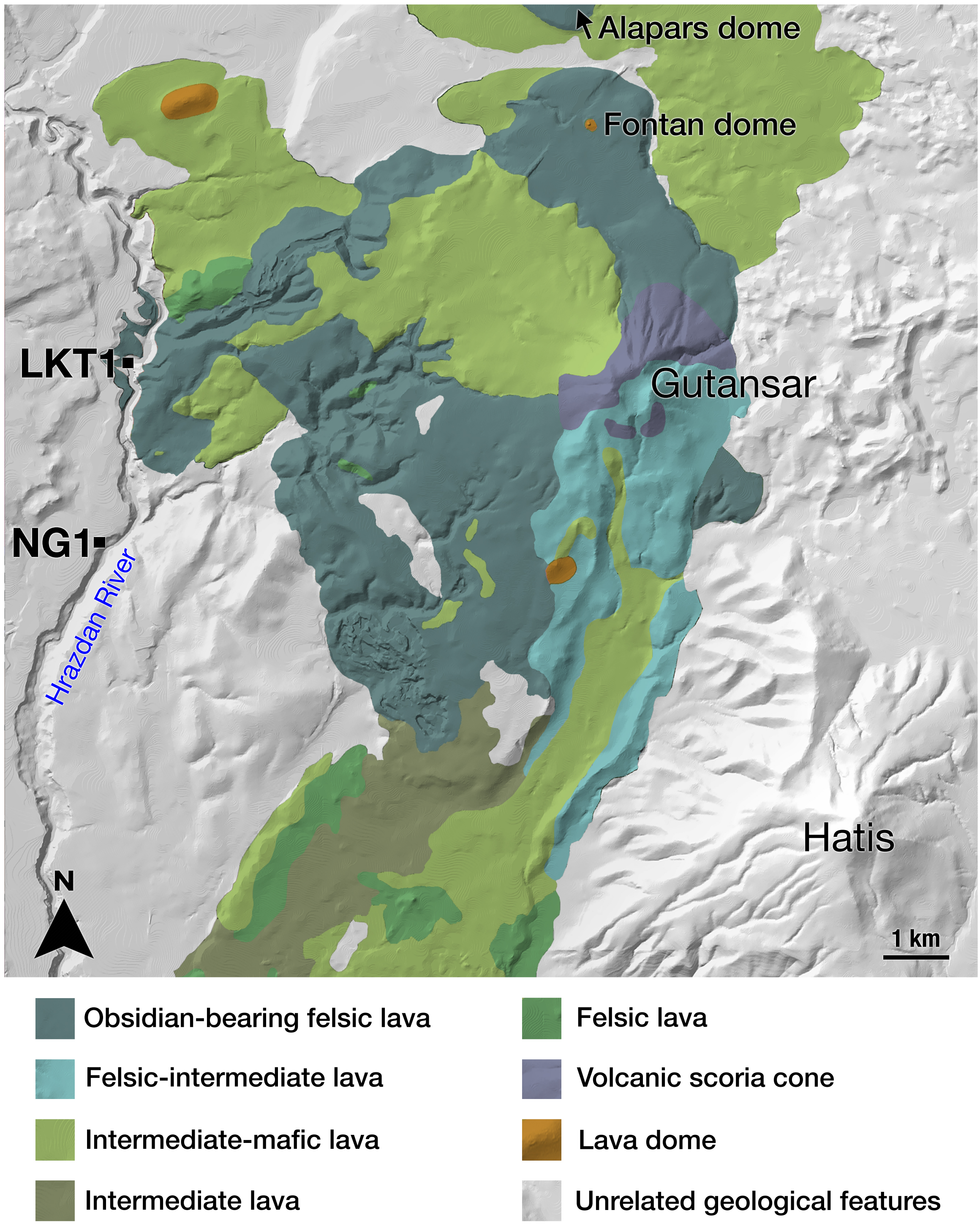

a
Mt. Arailer
Lower Pleistocene Arailer volcanic deposits
Lava 1
NG1
Lava 7
N
b
Gutansar volcanic cone
Lava 1
GVC volcanic deposits
Hrazdan River

Figure 3



Alapars dome
Fontan dome
LKT1
NG1
Hrazdan River
Gutansar
Hatis
N
1 km
Obsidian-bearing felsic lava
Felsic-intermediate lava
Intermediate-mafic lava
Intermediate lava
Felsic lava
Volcanic scoria cone
Lava dome
Unrelated geological features

Figure 4

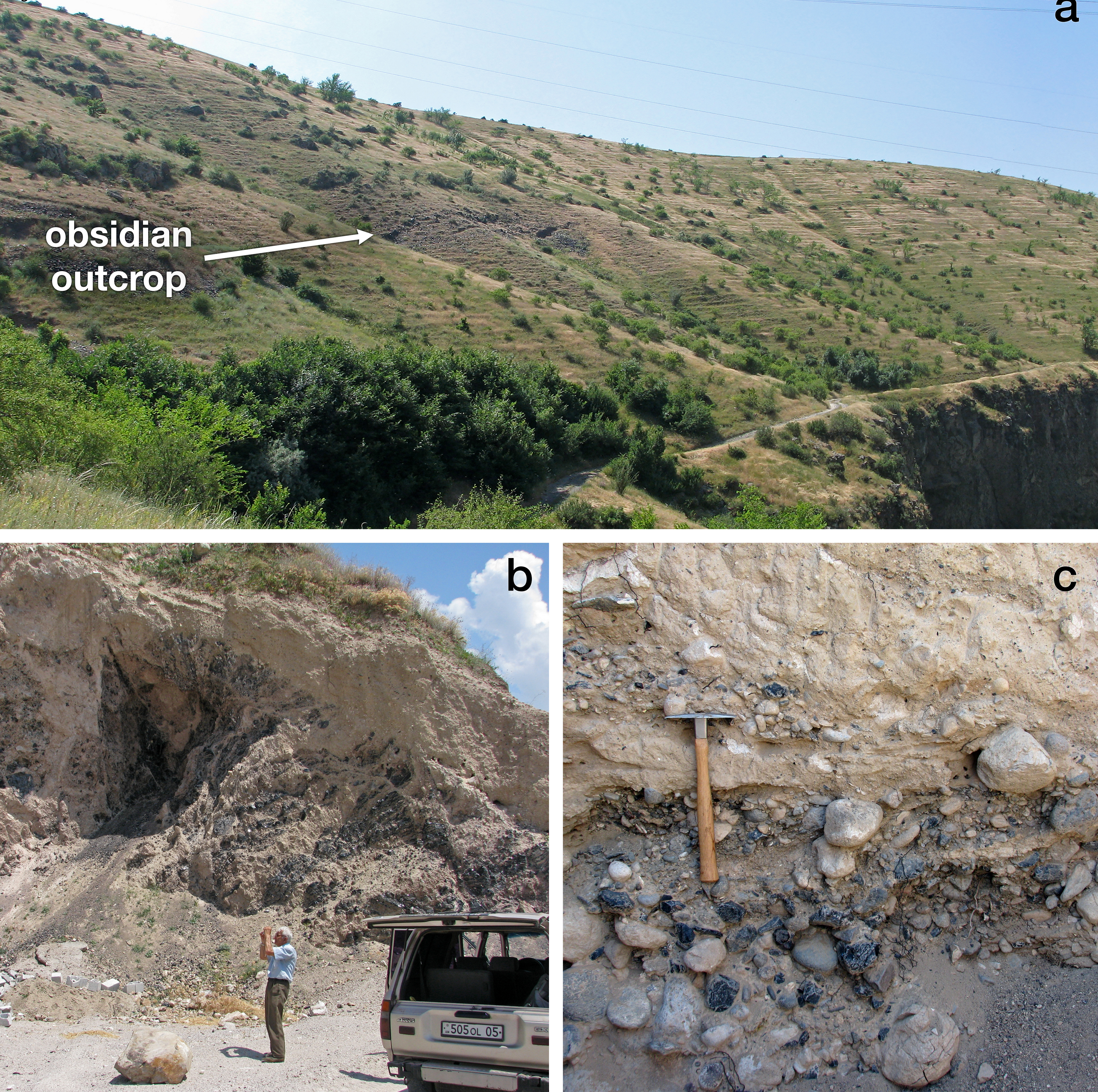


Figure 5

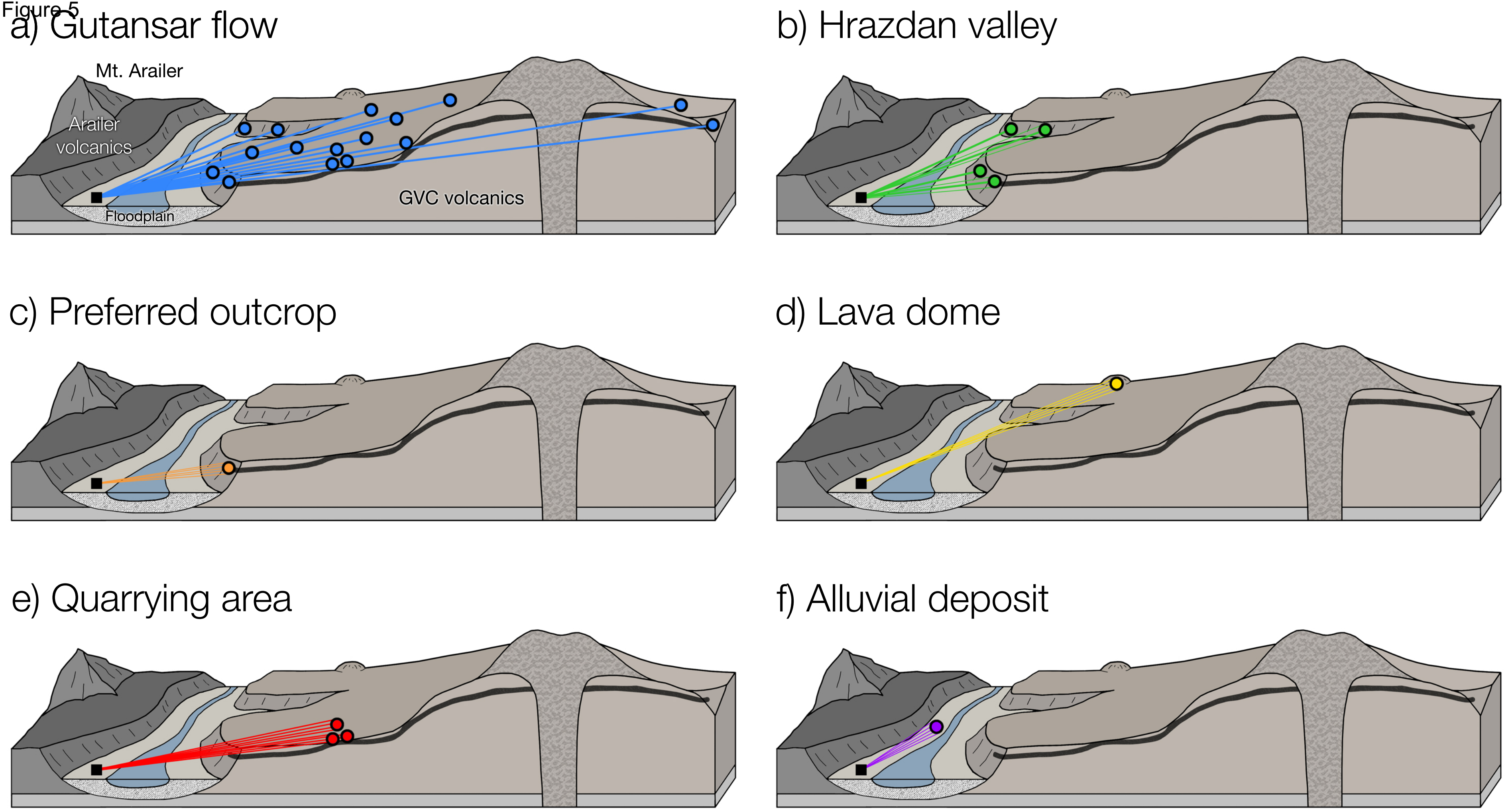

a) Gutansar flow
Mt. Arailer
Arailer volcanics
GVC volcanics
Floodplain
b) Hrazdan valley
c) Preferred outcrop
d) Lava dome
e) Quarrying area
f) Alluvial deposit

Figure 6

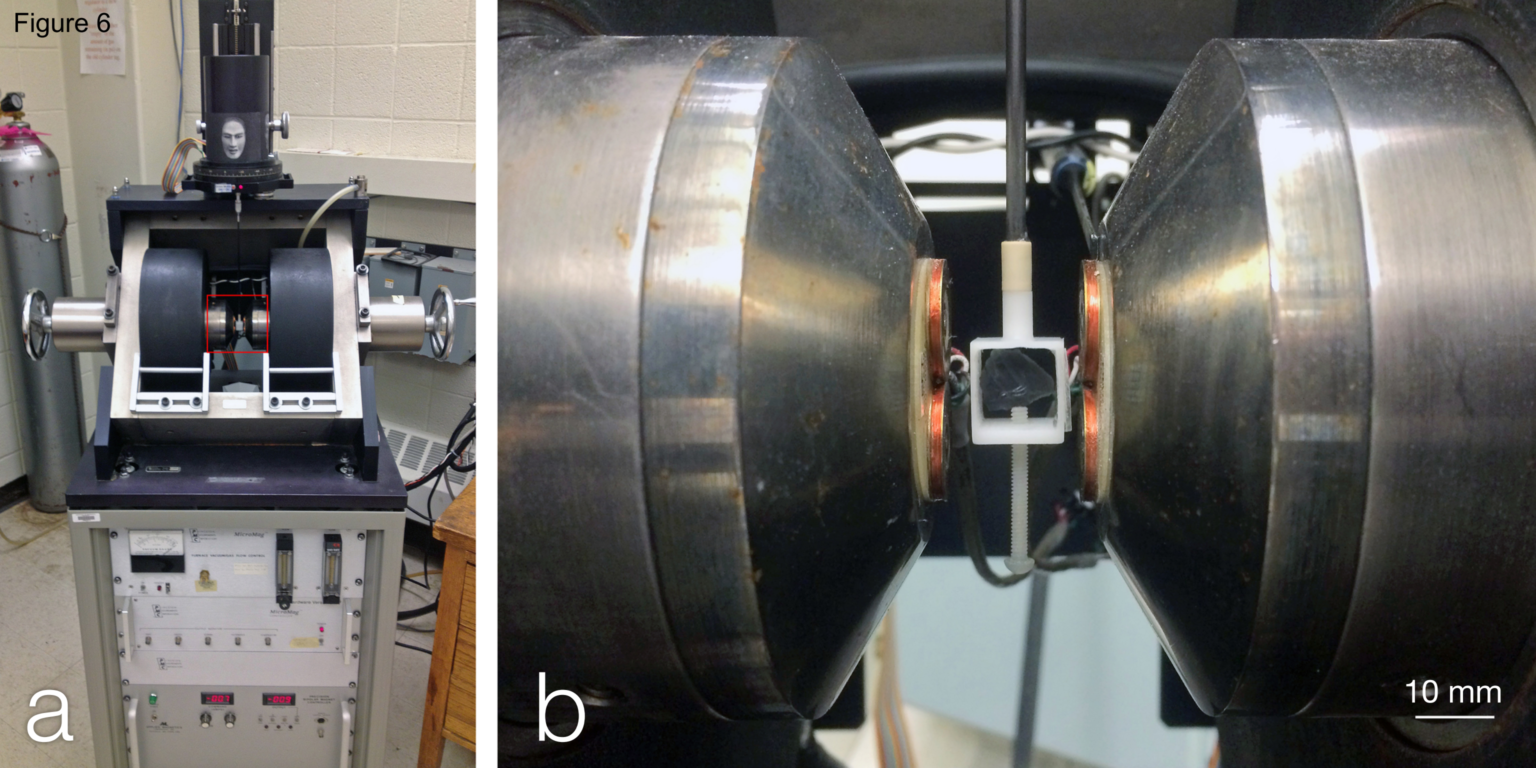


Figure 7

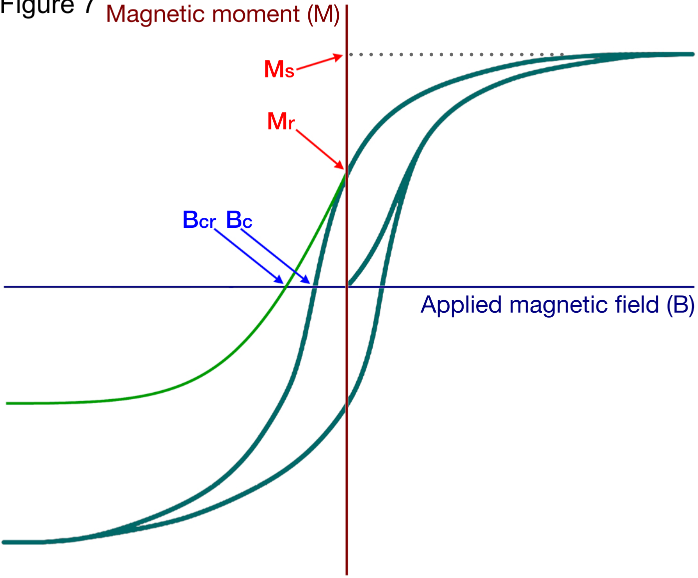


Figure 8

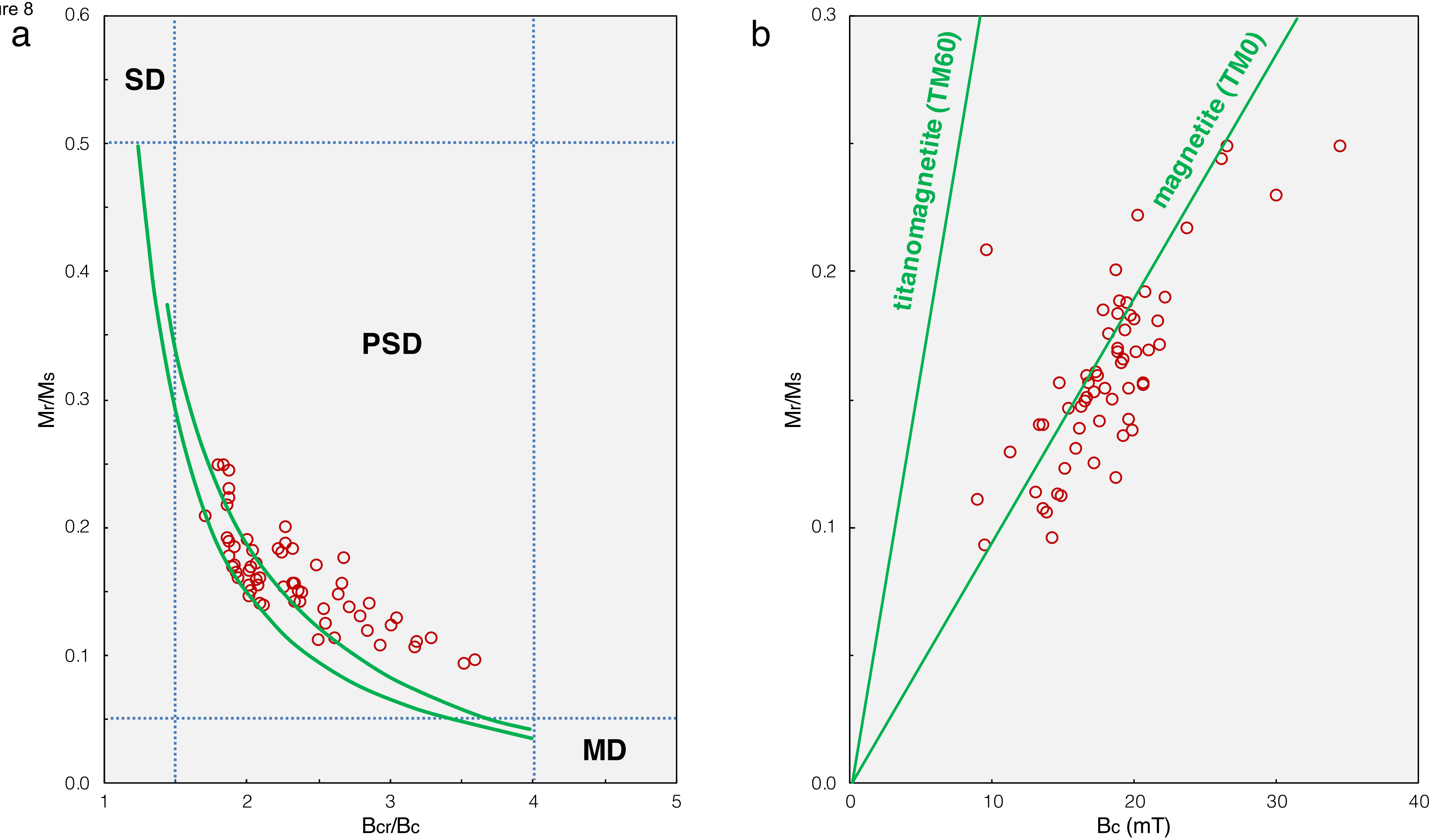
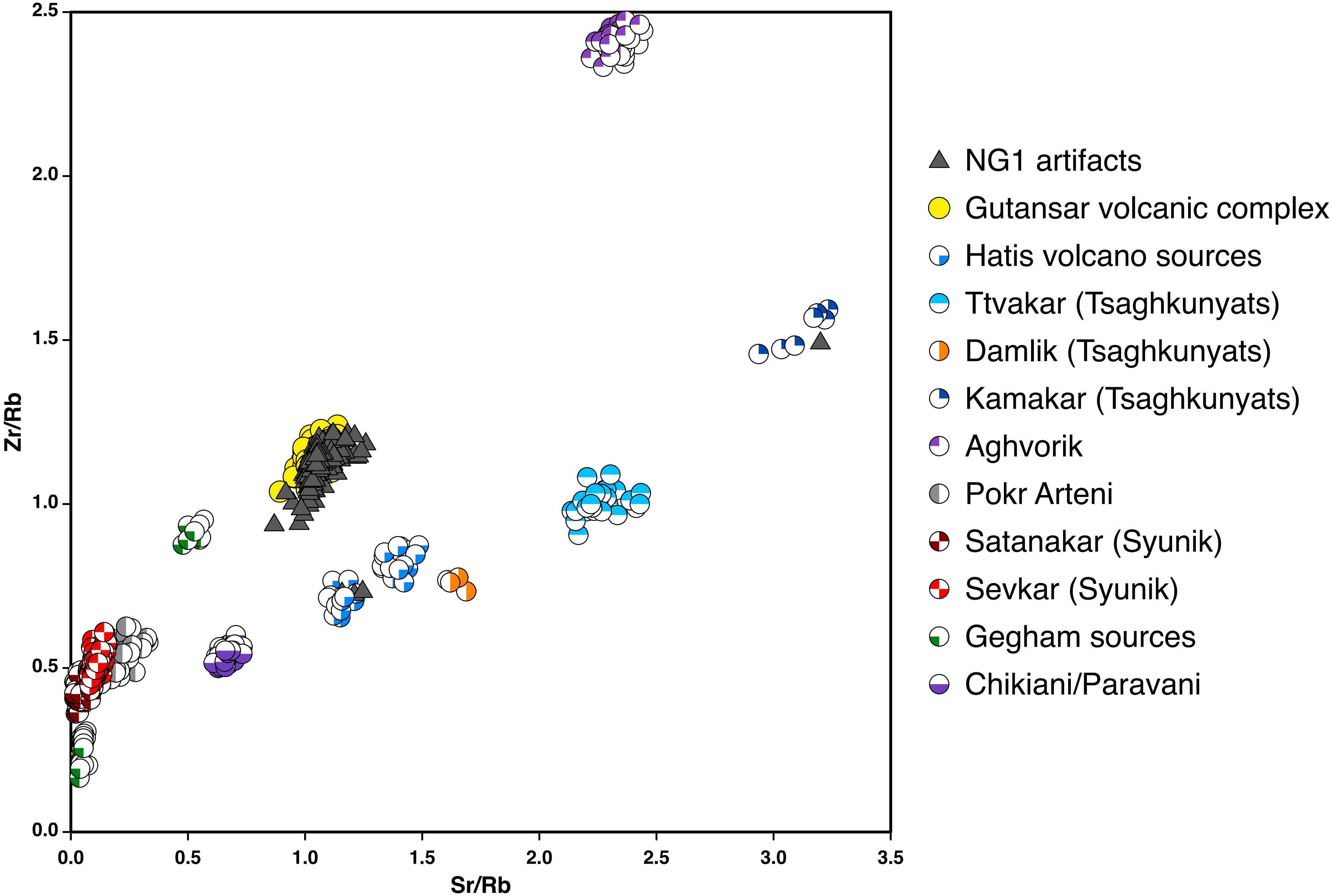

a
SD
PSD
MD
Mr/Ms
Bcr/Bc
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1
2
3
4
5
b
titanomagnetite (TM60)
magnetite (TM0)
Mr/Ms
Bc (mT)
0.0
0.1
0.2
0.3
0
10
20
30
40

Figure 9



2.5
2.0
1.5
1.0
0.5
0.0
Zr/Rb
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Sr/Rb
NG1 artifacts
Gutansar volcanic complex
Hatis volcano sources
Ttvakar (Tsaghkunyats)
Damlik (Tsaghkunyats)
Kamakar (Tsaghkunyats)
Aghvorik
Pokr Arteni
Satanakar (Syunik)
Sevkar (Syunik)
Gegham sources
Chikiani/Paravani

Figure 10

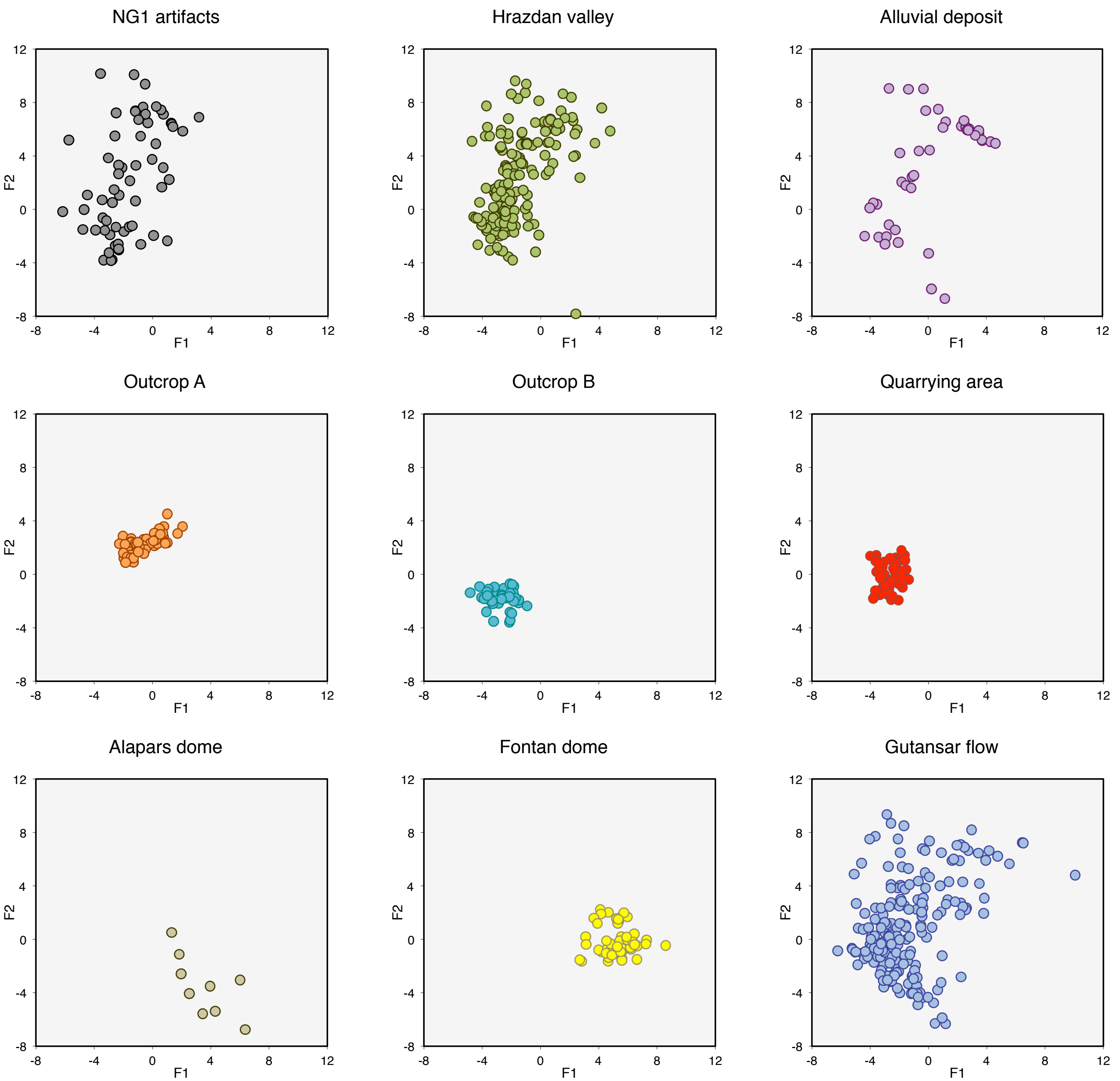

NG1 artifacts
Hrazdan valley
Alluvial deposit
Outcrop A
Outcrop B
Quarrying area
Alapars dome
Fontan dome
Gutansar flow
F1
F2
12
8
4
0
-4
-8

Figure 11

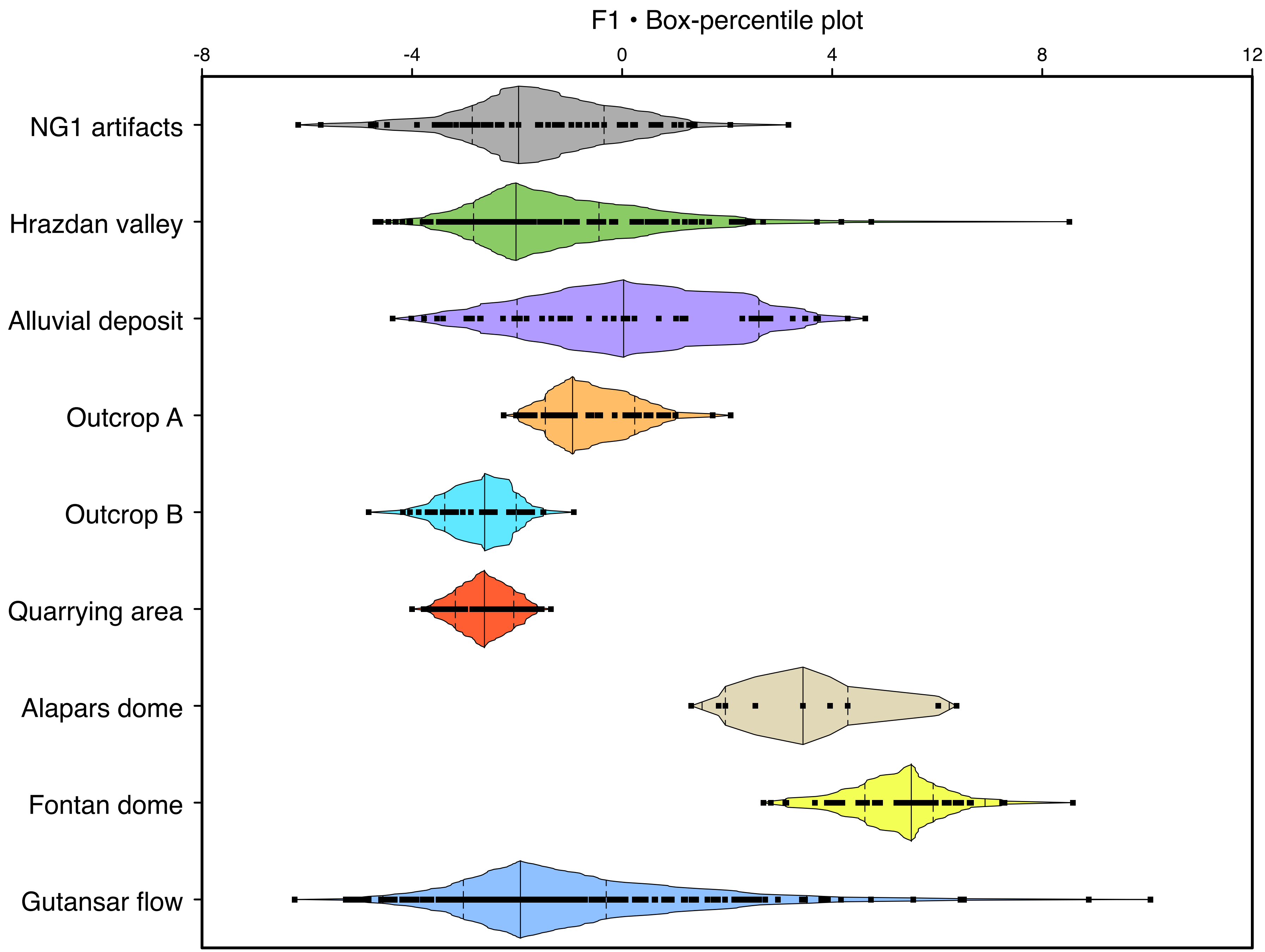
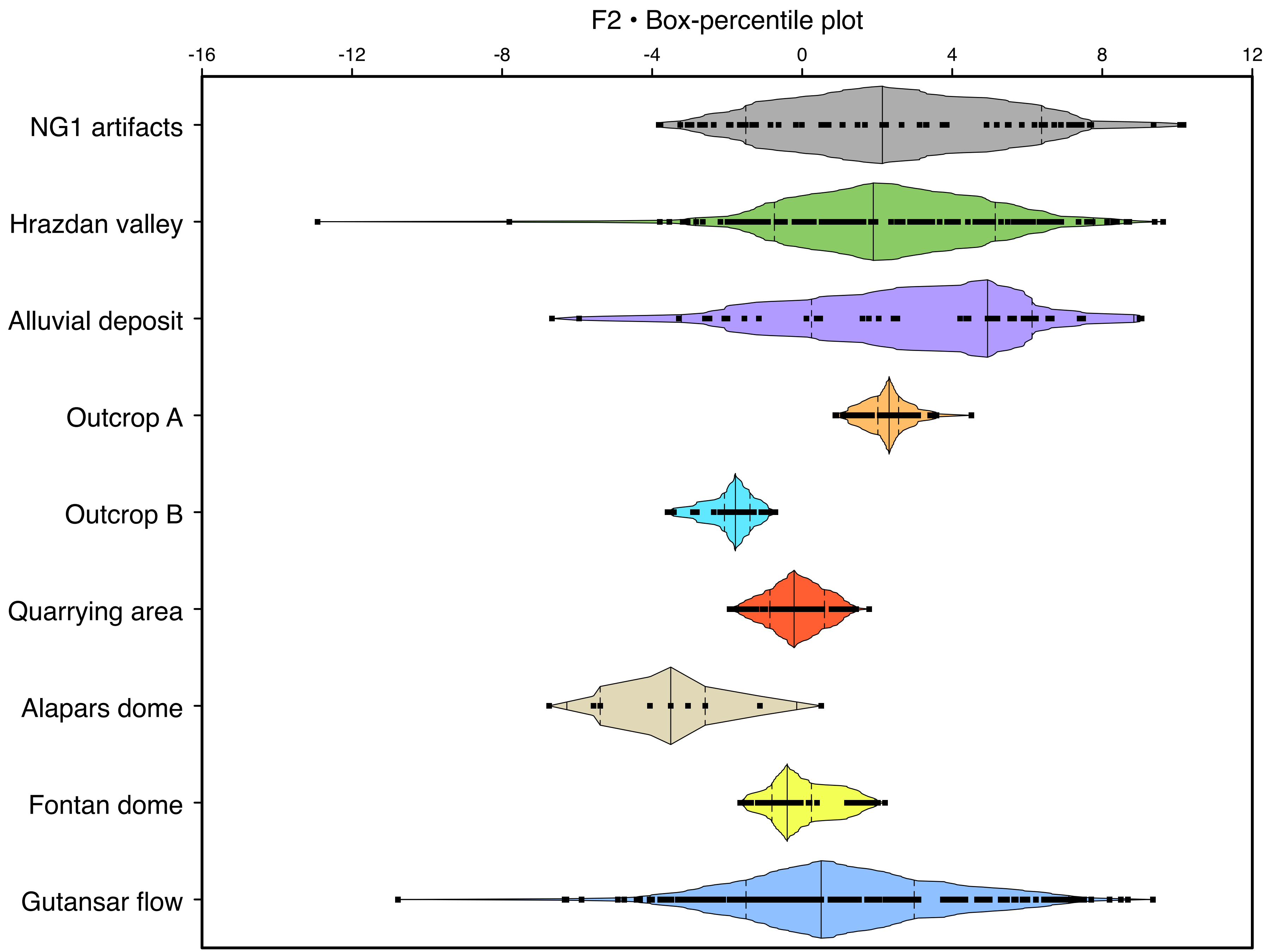

F1 • Box-percentile plot
-8
-4
0
4
8
12
NG1 artifacts
Hrazdan valley
Alluvial deposit
Outcrop A
Outcrop B
Quarrying area
Alapars dome
Fontan dome
Gutansar flow

Figure 12


F2 • Box-percentile plot
-16
-12
-8
-4
0
4
8
12
NG1 artifacts
Hrazdan valley
Alluvial deposit
Outcrop A
Outcrop B
Quarrying area
Alapars dome
Fontan dome
Gutansar flow

CRediT author statement

Ellery Frahm: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Visualization, Supervision, Project administration, Funding acquisition. **Caderyn Owen Jones:** Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Visualization, Funding acquisition. **Michael Corolla:** Methodology, Validation, Investigation, Resources, Writing - Review & Editing. **Keith N. Wilkinson:** Investigation, Resources, Writing - Review & Editing, Visualization, Supervision, Project administration, Funding acquisition. **Jenni E. Sherriff:** Investigation, Resources, Writing - Review & Editing, Visualization. **Boris Gasparyan:** Investigation, Resources, Writing - Review & Editing, Supervision, Project administration. **Daniel S. Adler:** Investigation, Resources, Writing - Original Draft, Supervision, Project administration, Funding acquisition.