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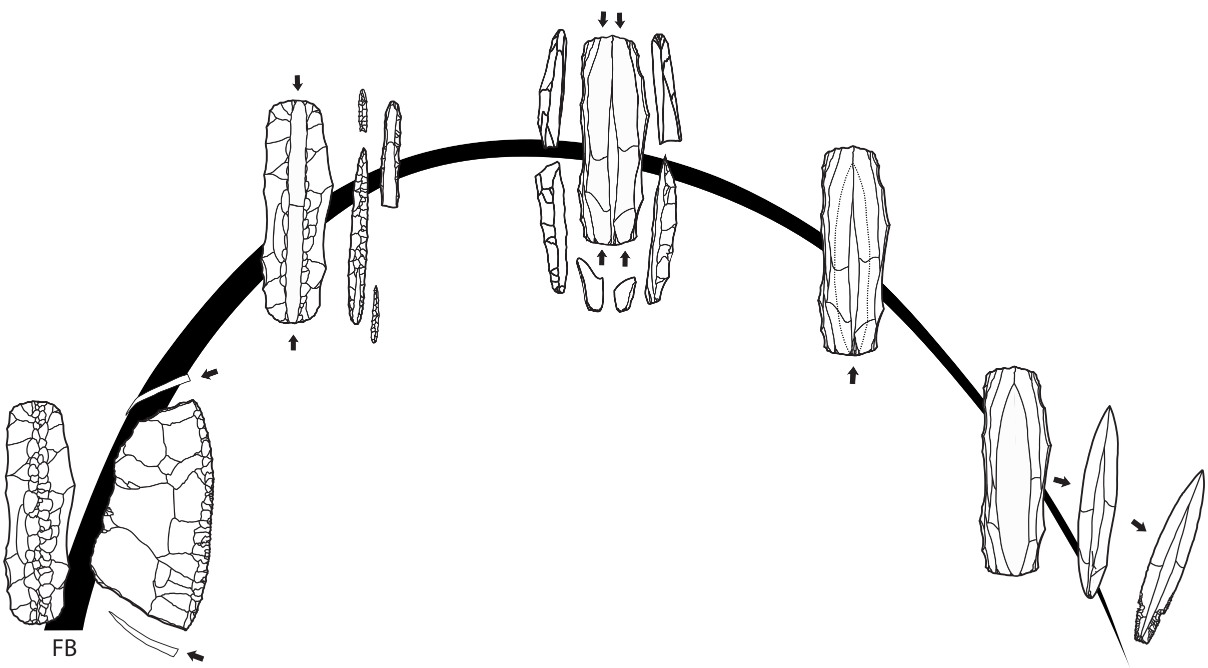

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This volume is dedicated to the late
Nikolaï Ottovitch Bader, Nur Balkan-Atlı, Edgar Peltenburg and Klaus Schmit

The opportunity to hear about ongoing field-work and new discoveries in parts of the Middle East—in spite of the devastation occurring elsewhere. Like our recently departed colleagues, whom we miss, we are united by a passion for prehistory. The PPN8 participants expressed this passion by reaching across ideological boundaries to share data, debate concepts and join in reveries that allow us to preserve the best of what makes the Near East so special to all of us.

Contents

18
The lithological landscape of the Greater Petra Region, Southern Levant. Availability of chert and other abiotic resources

Christoph Purschwitz

Abstract

This contribution presents the results of a chert raw material survey that was carried out in the Greater Petra Region during September to October 2012. This research was part of a PhD thesis (Purschwitz 2017) aimed at providing an archaeo-geological framework of chert raw material availability and geological distribution in the Greater Petra Region. It also aims at correlating the Flint Raw Material Group-system (hereafter FRMG, Muheisen *et al*. 2004) with the geological environment of related source areas. The FRMG-system was initially established from artefacts found in the Basta excavations (FRMG 1–9, Muheisen *et al.* 2004) and was later extended according to the chert spectrum present at other sites in the Greater Petra Region, including Ail 4, Ba'ja, Beidha and Shkârat Msaied (Purschwitz 2017). The correlation of site-based raw material classifications with their geological availability and distribution is a methodological key used to investigate the procurement modes involved with specific raw materials and is an important contributor to the reconstruction of prehistoric lithic economies.

The raw material survey revealed that primary sources of chert raw materials are restricted to a few geological formations. However, these sources have noticeable differences in the quality, quantity and regional distribution of specific FRMG. The archaeologically established FRMG shows a high degree of correlation with certain geological formations of the Greater Petra Region. That makes chert a promising material to analyse, along with a reconstruction of its related modes of acquisition and distribution.

Introduction

Although chipped lithics is the most abundant artefact category found at southwest Asian prehistoric sites, raw material provenance studies on chert, in contrast to obsidian, have been generally neglected (cf. Bar-Yosef 1991: 235; Delage 2007a; Olszewski & Schurmans 2007: 164–165). One major reason for this bias is due to methodological difficulties connected to geochemical provenance analysis among cherts and siliceous stones (cf. Andrefsky 2008: 78–79). Another reason may in fact be the superabundance of chert raw materials in most of the Levant´s regions (cf. Bar-Yosef 1991: 235), which makes the identification of outcrops exploited in specific prehistoric periods like looking for a needle in a haystack. Additionally, the general availability of cherts and other knappable stones often led researchers *a priori* to assume a local origin (e.g. Mortensen 1970; Lechevallier 1978a, b; Gopher 1989; Garfinkel 1994; Gopher *et al.* 1994). This is somewhat surprising as often considerable efforts are spent by many lithic analysts to describe, characterise and group chipped lithic artefacts according to colour, texture and other features. Systematic efforts to change this site-centric (or 'on-site') view of chert raw material availability towards an environmental approach to investigate the lithological and geological landscape around sites are limited in number, but receiving increasing attention (e.g. Quintero 1996; Muheisen *et al.* 2004; Delage 2007b, c; Olszewski & Schurmans 2007; Borrell 2010; Borrell & Vicente 2012; Henry 2014; Nazaroff *et al.* 2013; Henry *et al.* 2014; Purschwitz 2013). The importance of an 'off-site' perspective is also illustrated by the increasing number of early Neolithic chert mines and quarries (Wadi Huweijir, Ramat Tamar, Mitzpe Ramon, Har Gevim, Jabal Jiththa, Nahal Dishon, Giv'at Rabi), which clearly show that chert procurement sites often were not situated in the immediate vicinity of the communities exploiting them (Barkai & Gopher 2001; Muheisen *et al.* 2004; Gopher & Barkai 2006, 2011; Schyle 2007; Quintero 2010; Barzilai & Milevski 2015; Oron *et al*. this volume).

Another issue concerns the very few standardised differentiations, characterisations and descriptions of cherts and related knappable stones in southwest Asian archaeological publications. The spectrum of approaches ranges from minimalistic designations (e.g. flint or chert) to very detailed raw material classification systems (e.g. Gebel 1994; Muheisen *et al.* 2004; Henry 2014). The latter are often established

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by using predominantly macroscopic raw material features such as colour, colour pattern, texture, translucency, homogeneity, inclusions, microfossils, characteristics of primary or secondary cortex, shape of natural chert bodies and others. The variety of chert classification approaches considerably complicates inter-site comparisons. The transfer of data and information on raw material use are difficult to achieve, or only possible at a very general level (Purschwitz 2017: 11).

This research aims at providing an archaeo-geological framework on raw material availability and geological distribution in the Greater Petra Region. It also aims at correlating the Flint Raw Material Group-system (hereafter FRMG, Muheisen *et al.* 2004) with the geological environment of related source areas. The FRMG-system was initially established from artefacts found during the Basta excavation (FRMG 1–9, Muheisen *et al.* 2004) and was later extended according to the chert spectrum present at other sites in the Greater Petra Region, including Ail 4, Ba'ja, Beidha and Shkârat Msaied (cf. Purschwitz 2017). The correlation of site-established raw material classifications with their geological availability and distribution is a methodological key used to investigate the procurement modes involved with specific raw materials: it is an important contributor to the reconstruction of prehistoric lithic economies (Purschwitz 2017 and this volume, chapter 19).

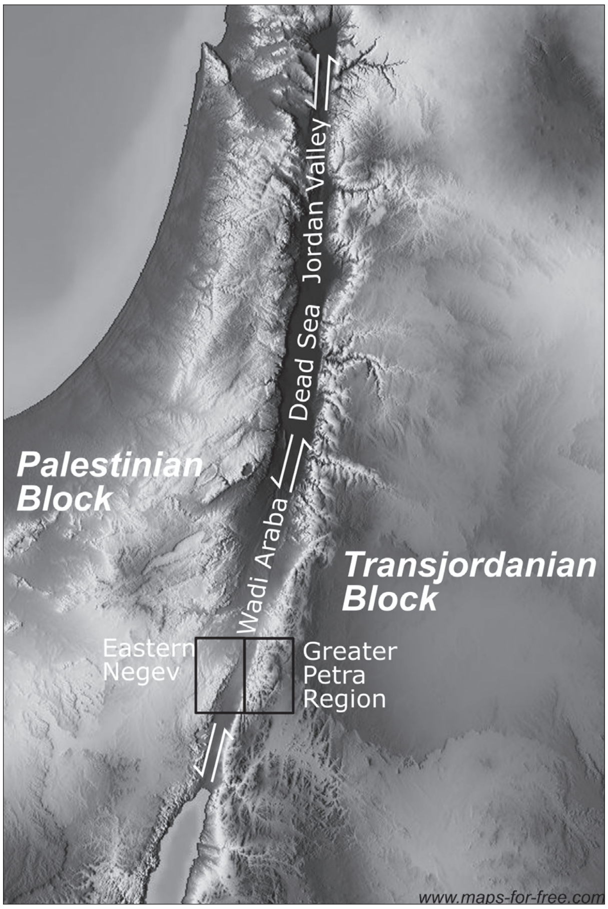

Figure 1. Satellite image of the Southern Levant showing the Dead Sea Transform and the position of the map inlays of the eastern Negev (left, cf. Fig. 5) and the Greater Petra Region (right, cf. Figs 2, 4)

Geological framework of the Greater Petra Region

The impact of the Dead Sea Transform (DST)

The Dead Sea Transform (DST) is the northern part of the Great Rift Valley which extends over 6000km from southeast Africa to the Northern Levant. The DST starts at the Gulf of Aqaba in the south and continues to the Taurus collision plate in the north (**Fig. 1**). It is a north-south striking shear zone between the African and Arabian tectonic plates, which is characterised by the left-lateral displacement of both plates (cf. Garfunkel 2014). The DST shear-zone, which is also called the Dead Sea Rift Valley, is composed of several topographic units that are, from south to north: the Wadi Araba, the Dead Sea Basin, the Jordan Valley, the Beqaa and the al-Ghab Valley (Garfunkel 2014). The Palestinian block, which lies on the African plate, moves southwards, while the Transjordanian block as part of the Arabian plate moves to the north. This lateral displacement is considered to have started during the early to mid-Miocene, moving with an average speed of 5 to 7mm per year for the last 5 million years (Ben-Avraham 2014). This north-south movement is visible by the lateral displacement of geological formations east and west of the Rift Valley, such as the copper ore deposits of Timna and Wadi Feinan. Both ore deposits were formed during the Cambrian era as one coherent ore layer that became divided by the separation of the DST up to 107km (Hauptmann 2007; Garfunkel 2014).

The DST has, thus, had considerable impact on the distribution of chert-bearing deposits on both sides of the Rift Valley as the cherts generally formed in pre-Miocene deposits. The results of chert availability in the Greater Petra Region, therefore, cannot be transferred to the geological environment of the Negev—and *vice versa*. FRMGs that are found in the Greater Petra Region may or may not be present in the eastern Negev, since we have to expect a different chert spectrum in the eastern Negev.

The lithostratigraphic sequence of the Greater Petra Region

The geographical and topographical position of the Greater Petra Region in the Eastern Rift Valley allows the exploitation and extreme diversity of rock and mineral resources from the geological layers and formations (**Table 1**). The oldest geological layers in this region date to the late Proterozoic and are more than 600 million years old. They are mostly referred to as crystalline or the pre-Cambrian basement, and are part of the 'Nubian-Arabic Shield' (Bender 1974: 29).

Period	Epoch	Stage	**Greater Petra Region** Mapping units & abbreviations after National Resource Authority (e.g. Barjous 2003)		Bender (1968, 1974)		Group	**Negev** Mapping units & abbreviations Israel Geological Survey (after Sneh et al. 1998)		Group
Quaternary		Holocene	Soil, Alluvium and Wadi Sediments (S/Al/Alf/Als)		Soil			Alluvial Sediments (q)	Sand dunes (qs)	*Tiberias - Dead Sea*
			Early Holocene Alluvial Fan / Alluvium Sediments (Alfo/Alo)							
		Pleistocene	Fluviatile and Lacustrine Gravels (Pl/Plc/Plf/Plg/Pls)		Fluviatile Gravel					
			Lisan Marls		Lisan Marls			Lisan Marls (ql)		
			ar-Risha Gravels							
			Basalt (B)		Basalt					
		Pliocene	Dana Conglomerate (DC)	Dhira' Ibn Salih Conglomerate (DS)	Upper Syntactic Conglomerate (tt3)					
Tertiary				Wadi Bustan Calcarenite (WB)	Lower Syntactic Conglomerate (tt3)			Rhyolithic Quartz Porphyr		
		Miocene	*Unconformity*					Hazeva Fm. (m)		
								Neogene volcanism (βm)		
	Eocene	Upper	Umm Rijam Chert Limestone (URC)		Chert Limestone Unit (tt1)		*Belqa*	Qezi'ot Fm. (ue)		
		Middle						Matred Fm (enm)		*Avedat (eav)*
		Lower						Mor, Nizzana & Horsha fms. (enm; ea)		
		Palaeocene	Muwaqqar Chalk-Marl (MCM)		Chalk-Marl Unit (c2)			Taqiya Fm. (mp)		*Mount Scopus (sp)*
Cretaceous	Late	Maastrichtian								
		Campanian	Al-Hisa Phosphorite (AHP)		Phosphorite Unit (c2)			Mishash Fm. (ca)		
			Amman-Silicified Limestone (ASL)		Silicified Limestone Unit (c2)					
		Santonian	Wadi Umm Ghudran (WG)					Menuha Fm. (sc)		
		Conacian								
			Wadi as-Sir Limestone (WSL)		Massic / Sandy Limestone Unit (c2)		*Ajlun*	Zihor Fm. (con)		*Judea*
		Turonian						Gerofit Fm. (t)		
			Fuhays / Hummar / Shu'ayb (F/H/S)		Echinoid Limestone Unit (c2)					
		Cenomanian			Nodular Limestone Unit (c2)			Ora Shale Fm. (t)		
			Na'ur Limestones (NL)					Hazera Fm. (c)		
	E.	Albian	Karnub Sandstones (KS)		Massive White Sandstone (c1)			Hathira Fm. (lck)		
Unconformity			*Unconformity*					Unconformity		
Jur.	Middle							Mahmal, Zohar & Matmor fm. (jm)		
	Lower							Inmar Fm. (jl2)		
Unconformity								*Unconformity*		
Ordovician			Disi Sandstones (DI)		Massive Whitish Weathered Sandstones (c1)		*Ram Sandstones*	*Not exposed*		
Cambrian			Umm Ishrin Sandstones (IN)		Massive Brownish Weathered Sandstones (cb)					
			Abu Khushayba Sandstones (AK)	Burj Dolomite Shale (BDS)	White Fine Sandstone Unit (cb1)	Dolomite Lime-stone Shale Unit (cb2)				
			Salib Arkosic Sandstones (SB)		Bedded Arkosic Sandstone / Basal Conglomerate (cb1)					
"Pre-Cambrian"/ Late Proterozoic			Al Bayda' Quartz-Feldspar Porphyry (BA)		Saramuj Conglomerate / Greywacke Series		*Ahaymir Volcanic*	Rhyolithic Quartz Porphyr (p)		
			Mufarqida Conglomerate (MC)					*Not exposed*		
			Musaymir Effusive (MR)							
			Qusayb Rhyolite (QB)							
			Harun Microgranite (HG)				*Finan Granitic*			
			Fidan Syenogranite (FN)							
			Rachel Hornblende Quartz Diorite (RH)		Magmatite (Igneous rocks)					
			Huwar Two-Mica Granite (HR)				*Rahma Foliated*			

Table 1. Lithological sequence of the Greater Petra Region and the Negev

The basement is composed of plutonic rocks (such as quartz diorite, granodiorite) associated with magmatic rocks (hornblende-gabbro, hornblendite, among others) and high pressure kata-rocks (e.g. paragneiss). Metamorphic sediments such as clay slate and Palaeozoic eruptive rocks (quartz porphyry, porphyry) are also found. Due to the high pressure and its position deep in the earth's crust, the rocks of the pre-Cambrian basement were over time repeatedly 'metamorphosed' (Bender 1974: 29–37). The pre-Cambrian basement is mainly exposed at the eastern Wadi Araba and the Eastern Rift Mountains, where it was lifted by plate tectonics due to the drifting of the African and Arabian plates, and later became exposed to the surface by crystal thinning during the Pliocene-Pleistocene about 5.1–1.5 mya (Waitzbauer & Petutschnig 2004: 91, 104).

The basement is covered in the eastern area of the Rift Mountains and the Petra Sandstone Shelf by a thick series (ca 500m) of sandstone formations, which were formerly known as 'Nubian Sandstones', but are today referred to as the Ram-Sandstone group. These sandstones were deposited during the Palaeozoic period of the Cambrian (541 to 485 mya) and the Ordovician (485–443 mya). The lowest formation of the Ram Sandstone Group is the brown, arkosic to sub-arkosic sandstone of the Salib Arkosic Sandstone Formation (SB), which can reach a regional thickness of up to 70m. The SB sandstones are covered by pale grey sandstones of the Abu Kusheibah Sandstone formation (AK) with a maximum thickness of 120m (Barjous 2003: 21–22). In the Wadi Feinan area, the AK is replaced by the massive, partly marine carbonate deposits (up to 70m thick), which are called Burj Dolomite Shale-Formation (BDS), which indicate the temporal advance of the Tethys Ocean during the early to middle Cambrian (Rabb'a 1994: 21). The copper ore deposits of Wadi Feinan and Wadi Abu Kusheibah were mainly mineralised within these early to middle Cambrian formations (Barjous 2003: 67; Hauptmann 2007: 47).

On top of the AK and BDS follow the multi-coloured Umm Ishrin Sandstones (IN), which reach a regional thickness of 300m maximum. The middle stratum of the IN-sequence shows the fascinating colour patterns, in which the famous Nabeatean-Roman façade graves of Petra were carved. The coloured sandstone is caused by small amounts of minerals (such as iron, manganese and copper) that became distributed by intruding and circulating water into bizarre patterns (Rothe 1991: 205; Barjous 2003: 23). The IN is overlaid by the massive white sandstones of the Disi Sandstone Formation (DI), which are already of Ordovician age (485–443 mya) and reach a regional thickness of up to 250m (Barjous 2003: 24).

The limestone escarpment is marked by a gap in the geological sequence as Cretaceous layers lay on top of the DI Sandstones. No formations of the Silurian to the Jurassic (a geological time span of almost 300 mya) have been exposed in southern Jordan. The Cretaceous deposition starts with the Lower Cretaceous Kurnub Sandstones (KS, Berriasian to Albian Stages, ca 145 to 100 mya), which consists of white, yellow to red or multi-coloured and banded quartzitic sandstone with a thickness of up to 160m (Barjous 2003: 26–28; Baaske 2005: 9–10; Powell & Moh'd 2011: 37). Late Cretaceous layers follow the KS. The Late Cretaceous epoch (about 100 to 66 mya) is generally divided into the 'Ajlun Group' and the 'Belqa Group' (cf. Powell & Moh'd 2011: 37). The lower 'Ajlun-Group' is composed of the geological formations of the Na'ur Limestones (NL, Cenomanian), the Fuhays/Hummar/Shu'ayb group (F/H/S, Cenomanian to Turonian) and the Wadi as-Sir Limestones (WSK, Turonian to Conacian). The Ajlun-Group predominantly consists of shallow-marine carbonates (such as hard dolomitic limestone, marl and wackestone), which were deposited on a rimmed shelf (Powell & Moh'd 2011: 37). The upper 'Belqa-Group' comprises Late Cretaceous to Eocene formations such as the Wadi Umm Ghudran (WG, Conacian to Santonian), the Amman Silicified Limestones (ASL, Campanian), the Al-Hisa Phosphorites (AHP, Late Campanian), the Muwaqqar Chalk Marls (MCM, Maastrichtian to Palaeocene) and the Umm Rijam Chert Limestones (URC, Eocene). The Belqa-Group consists mainly of chalk, chert and phosphorites which were deposited in a pelagic or semi-pelagic ramp setting (Powell & Moh'd 2011: 39). However, there is a clear decrease of marine influence in the sedimentary milieu in favour of terrestrial and limnic components in the upper part of the Belqa-Group (Waitzbauer & Petutschnig 2004: 93).

Regionally, the URC layers are covered by the Dana Conglomerates formation (DC, late Oligocene to Miocene), which can reach thicknesses up to 450m and is composed of rearranged and eroded Cretaceous to Eocene formation constituents that were deposited in a tectonically very active environment (Barjous 1992: 43; 2003: 45). Similarly, during the Pliocene and Early Pleistocene, the Eastern Rift Valley was impacted by massive tectonic activity such as lifting and faulting due to the DST. This was accompanied by intensified volcanism, which resulted in the deposition of eruptive rocks and in massive basalt ceilings (cf. Weinstein & Garfunkel 2014). In the Greater Petra Region, basalts of this period are confined in their distribution, being exposed in the northeast near Dana and to the north and east of Shobak (Barjous 1988). The most recent geological depositions (Pleistocene to Holocene) are marked by the infilling of valleys and wadis where they became important contributors to the regional groundwater regime (Rothe 1991: 206).

Chert bearing deposits of the Greater Petra Region and the eastern Negev

According to geological publications of the Greater Petra Region, chert concretions can be embedded in several Cretaceous to Tertiary geological formations (Bender

1968, 1974; Barjous 1988, 1992, 1995, 2003; Kherfan 1998, 2002; Moumani 2002; Tarawneh 2002, 2004; Baaske 2005). The Eocene URC and the Campanian ASL are seen as most abundant in chert layers, while others such as the NL, WSL, WG, AHP and MCM Formations can bear chert concretions, but only in minor quantities. Occasionally, chert concretions are found in late Oligocene to Pleistocene deposits, where they are in a secondary position. Examples of such deposits, often local in extent, are the DC at Wadi Bustan (Barjous 1992: 41), the Pleistocene ar-Risha Gravels (RG) west of Jabal ar-Risha (Barjous 2003: 45) and the palaeolake deposits (Ld) on the western shoreline of the Ma'an Palaeolake (Tarawneh 2004: 17–18; see also below). In the eastern Negev (Baer *et al.* 2014; Sneh *et al.* 2014), chert concretions have been recorded at the Hazera-Formation (c2, Cenomanian), the Gerofit-Formation (t, Turonian), the Mishash-Formation (ca, Campanian) and the Eocene Mor, Nizzana and Horsha-Formation (eav).

Raw material classification

The raw material classification system used in this analysis follows that established at Neolithic Basta (Gebel 1994; Muheisen *et al.* 2004). This system classifies the raw materials of archaeological artefacts according to their mineral or rock qualities into chert, obsidian, quartzite, orthoquartzite, limestone or other such classifications. Chert is further classified according to macroscopic qualities such as colour, colour pattern, raw material shape and size, characteristics of natural surfaces, texture, inclusions, translucency, lustre and flaking ability into the various Chert Raw Material Groups (FRMG). At Basta, nine different groups (FRMG 1 to FRMG 9) were distinguished. Additional groups were established for cherts that occur in minor quantities and do not fit into one of the nine major groups, for example (FRMG 45), for thermally altered and burnt cherts (FRMG 48), as well as for undetermined (i.e. often patinated) cherts (FRMG 49).

The original Basta classification was then systematically extended according to the chert spectrum based on evidence at the PPNB sites of Ail 4, Ba'ja, Beidha and Shkârat Msaied (**Table 2**). New FRMG such as FRMG 10 and 11 were added, as some sites provided larger samples of related chert artefacts. For others, it was possible to split them according to their macroscopic characteristics into subgroups. This procedure was applied for FRMG 3, which was subdivided into FRMG 3b ('brecciated'), 3d ('dull'), 3g ('glossy') and 3p ('phosphatic?'). Similarly, FRMG 5 was divided into the subgroups 5a and 5b. There are also differences among FRMG 2 that comprise both nodular and tabular variants from different geologic sources. The tabular variant is very characteristic and appears to be confined to Jabal Jiththa, which is why the name Jiththa-Flint is proposed here. However, at a macroscopic level the FRMG 2 subgroups can only be distinguished if considerable amounts of cortex are preserved. FRMG 25 comprises all kinds of pink-purple cherts and is not considered to be a homogeneous raw material group. FRMG 26 represents a chert type that is very characteristic of the PPNB-site of Wadi Abu Tulayha (Western Jafr Basin) some 25km northeast of the Greater Petra Region.

Survey methodology

A total of 15 survey areas were chosen according to their geological settings, distance and accessibility to the early Neolithic sites of Ail 4, Basta, Beidha, Ba'ja, and Shkârat Msaied (**Fig. 2**). Also, regional topographic units that could be etymologically connected to cherts, such as Jabal Abu Sawwana, Jabal Umm Sawwana, or Umm Sawwana (arab. *sawwan* = chert), were included in the survey. The majority of the surveyed areas comprised surface-exposed geological formations that were expected to be rich in chert sources, such as the limestone formations of the ASL and URC. However, as has been noted from the geological publications (see above), chert concretions may also occur, though in minor quantities, in other formations such as the NL, WSL, WG, AHP or MCM units. Layers of these formations were investigated at selected spots for their raw material qualities. Additionally, wadis in the vicinities of the sites (e.g. Wadi 'Ail, Wadi Basta, Siq a-Ba'ja, Wadi al-Ghurab, Siq Umm al-Alda) were checked for their chert contents.

The survey was carried out by using transects and walking through the potentially chert-bearing geological formations or secondary source areas. Sources and outcrops of chert or other knappable stones (such as quartzite) were recorded as sample points. Each sample point was recorded using GPS, photographs and a site description. The description included a classification of the site (primary source, secondary source, extraction site, knapping ground etc.), a source description, a classification of the associated artefacts found there, as well as an estimation of their number, and a description of source-related raw materials (Raw Material Group, colour pattern, shape, dimensions, texture, cortex features and, for primary source areas, geological context of source). When possible, raw material samples were taken for petrographic analysis.

Results on raw material availability

Sixty-four sample points were recorded during the survey and 234 chert and rock samples were taken from both primary and secondary source areas (see Purschwitz 2017: Appendix 2–3 for sample points and coordinates) (**Fig. 2**). Several FRMG could be identified

	Context	Colour	Colour pattern	Shape, Size	Cortex	Texture	Inclusions	Translucency	Lustre	Flakeability
FRMG 1	URC	Brownish grey to dark brown	Very rare and irregularly distributed coloured clouds within the flint bodies	Lenticular to tabular (up to 50 cm)	White, Limestone (1-4mm)	Fine to coarse	Irregular distributed lime spots and gastropods (<0.5 mm)	Opaque	Dull	Good
FRMG 2 tabular	URC	Pale brown to yellowish brown	Irregular distributed milky clouds	Tabular, 10-20 cm with thick-ness between 1 to 5 cm	White, Chalk	Extra fine to fine	None	Opaque	Dull	Very good
FRMG 2 nodular	Unknown, Negev?		Irregular distributed milky clouds, sometimes banded	Nodular (> 10 cm)	White, Limestone (1-2mm)					
FRMG 3b "brecciated"	ASL / AHP	Various	Mosaics of various colours such as grey, black, beige, white	Tabular bodies of various dimensions	None	Fine to coarse (heterogeneous matrix)	Clefts and quartz-filled hollows, pieces of sand-stone, chert, and quartz	Opaque	Dull	Moderate to poor
FRMG 3d "dull"	ASL	Grey to light yellowish brown	Milky clouds, occasionally concentric banded	Amorphous nodules (5-15 cm) and tabular (various thickness)	White, Limestone (<0.1mm)	Fine to extra fine	None	Opaque to milky translucent	Dull	Very good
FRMG 3g „glossy"	Tempered FRMG 3d					Extra fine			High lustre, waxy	Very good
FRMG 3p „phosphatic?"	URC	Grey to dirty grey	Uniform	Lenticular nodules (10-50 cm)	White, Limestone	Fine to coarse	Regularly distributed dark spots (~0.5-1 mm) and gastropods	Opaque	Dull	Poor
FRMG 4	URC	Dark reddish brown	Uniform	Nodular, lenticular to tabular (unknown size)	White, Limestone (0.5-0.7mm)	Extra fine to fine	Fine lime inclusions (rare)	Opaque to slightly translucent	Faintly lustrous to dull	Very good
FRMG 5a	Unknown, J. Qalkhan?	Black to dark grey / greyish green	Mottled	Lenticular to semi tabular (unknown size)	White, Limestone (1-3mm)	Fine	Irregularly distributed whitish and blackish inclusion (foraminifera?) of varying density	Opaque to slightly translucent	Dull, occasionally faintly lustrous	Very good
FRMG 5b	URC	Black to very dark grey	Uniform	Nodular, to lenticular (unknown size)	White, Limestone (1-3 mm)	Fine	Irregular distributed lime inclusions	Opaque to slightly translucent	Dull	Very good
FRMG 6	Unknown, Negev?	Yellowish brown to slightly reddish brown / pale brown	Irregular clouds and concentric bands of lighter colours	Nodular / lenticular to semi-tabular (unknown size)	White, Limestone or Chalk	Extra fine	None	Milky translucent	Faintly lustrous	Very good
FRMG 7	Unknown	Dark reddish brown to light yellowish brown	Occasionally concentric bands of lighter colours	Nodular / lenticular to semi-tabular (unknown size)	White, Limestone	Extra fine to fine	None	Milky translucent	Faintly lustrous to lustrous	Very good
FRMG 8	ASL / AHP	White to very pale brown	Dark grey to black veins / streaks	Tabular bodies of various dimensions	None	Coarse	Many irregular clefts and quartz veins	Opaque	Dull	Poor
FRMG 9	URC	Light grey / light brownish grey	Occasionally concentric bands of reddish/pinkish colour	Lenticular to semi-tabular (up to 50 cm)	White, Limestone (1-2 mm)	Fine to coarse	Highly interspersed with tiny lime inclusions / gastropods	Opaque	Dull	Good
FRMG 10	ASL?	Very pale brown to very light yellowish grey	Irreg. clouds and concentric bands of darker colours	Nodular (unknown size)	Unclear	Coarse to fine	Occasional dark and white spots	Opaque	Dull	Good to very good
FRMG 11	ASL?	White / very pale brown to very light-yellowish brown	Milky clouds, occasionally concentric banded	Nodular to amorphous nodular (5-30 cm)	White, Limestone (1-2mm)	Fine to extra fine	None	Opaque to slightly translucent	Slightly high lustre to faintly lustre	Very good
FRMG 26	URC	Yellowish to greenish brown	Mottled	Lenticular (10-50 cm)	Tan, Limestone	Fine to extra fine	Irregularly distributed whitish (foraminifera?), buff-orange and blackish inclusions	Opaque	Dull	Good to very good

Table 2. Description of Flint Raw Material Groups (FRMG)

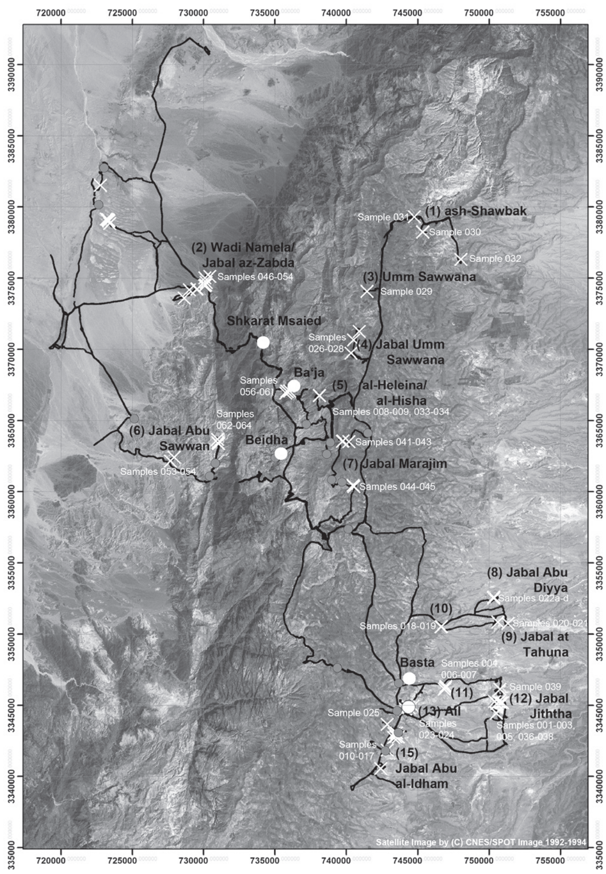

Figure 2. Satellite map of the survey area with survey tracks (black) and location of sample points (crosses); (Map: N. Rhensius; field records: C. Purschwitz, N. Rhensius, A. al-Suleiman)

within their primary geological settings. These include FRMG 1, 2 (tabular), 3b, 3d, 3p, 4, 5b, 8 and 9 as well as quartzite. Additionally, a few cherts similar to FRMG 2 (nodular), 5a, 10 and 11 were found, although only in secondary position. Therefore, the occurrence of FRMG 2 (nodular), 5a, 10 and 11 within the Greater Petra Region is likely, but not confirmed. We did not find any FRMG 3g, 6, 7, 25 (pink/purple cherts), 26 or orthoquartzite.

Primary source evidence

Among the attested FRMG, there is a high correlation between geological formation and related FRMG (**Table 3**). Eocene cherts of the URC comprise FRMG 1, 3p, 4, 5b, 9 and 26, while Campanian chert types of the ASL/AHP consist of FRMG 3b, 3d, 8 and possibly 10 and 11. Occasionally, cherts were also observed at other geological formations (WG, NL), although they occur there in very low densities and were generally of poor quality (heterogeneous, with many holes and cracks) and rarely match any established FRMG.

One exception is Jiththa-Flint (tabular FRMG 2) that is found abundantly in Pleistocene lake sediments (Ld) of the Ma'an Palaeolake at Jabal Jiththa. There, Jiththa-Flint is found associated with a few nodules of FRMG 1, and both are outside of their geological context of chert formation. The age of these palaeo-lake deposits is unclear, but is assumed to be contemporary with the palaeo-lakes of the Wadi al-Hasa area, which are dated between 140,000 and 40,000 BP (Moumani *et al.* 2003; Moumani *pers. comm.*) The geological origin of the tabular Jiththa-Flints remains, therefore, unclear. However, Jiththa-Flints still have a chalky primary cortex showing no signs of battering or abrasion. This would argue against a major displacement and Jiththa-Flints may originate from completely eroded Eocene chalk strata of the Jabal Jiththa.

The cortex types and shapes of chert bodies, as well as the chert matrix (texture and inclusions), show some diagnostic patterns that appear to correlate with chert age (**Fig. 2**, **Table 2**). Campanian nodular FRMG of the Greater Petra Region, such as FRMG 3d and 11, are often characterised by an irregular to amorphous shape with an extremely thin smooth or rough cortex that is not (or barely) visible in section. The matrix is homogeneous, fine to very fine grained and no inclusions or impurities were visible at 45x or 330x magnification levels. Other types of Campanian silicifications comprise thick bands of tabular chert beds (up to 1m in thickness) and have a similar matrix to FRMG 3d. However, the tabular FRMG 3d is often of poor quality, since it is often cracked due to the tectonic impact of the Rift Valley. At the slopes of the Eastern Rift Valley, brecciated cherts, which are often intermixed with sandstone (FRMG 3b) or other fragmented rocks (FRMG 8), are very common among the Campanian ASL/AHP strata. Both FRMG are easily recognisable among archaeological finds due to their very characteristic mosaic matrix.

Eocene cherts such as FRMG 1, 3p, 4, 9 and 26 are characterised instead by large lenticular nodules, which can measure up to 1m. The cortex is often limestone, sometimes chalky, with a variable thickness (up to several mm). The cortex is clearly distinguishable from the chert bodies in the section. The texture ranges considerably between coarse and fine grained. Inclusions of different types (most commonly gastropods and foraminifera) and sizes are very characteristic and give a dotted to mottled appearance to the matrix. Eocene FRMG appear to be more diverse and their distribution on a regional scale tends to be smaller than for Campanian FRMG. The quality of the Eocene and Campanian cherts is very good, with some exceptions in the Eastern Rift Valley area. Cherts of Eastern Rift Valley sources tend to be cracked and fractured due to intensive pressure, faulting and other tectonic impacts that have shaped the rift over millions of years.

Secondary source evidence

Generally speaking, the chert contents of the wadi fills provide a good overview of the raw material spectrum that occurs in the upstream drainage catchment. However, it has been observed that the quality of the chert diminishes, and that the chert bodies are characterised by completely abraded and battered surfaces even after short distances of wadi transport. Nevertheless, wadis are a convenient and attractive chert source, where cherts of various sizes, shapes and colours can easily, spontaneously and often without additional effort be collected according to daily demands.

Non-local raw materials?
The absence or near absence of some FRMG in the survey area, such as nodular FRMG 2, 3g, 5a, 6, 7, 25, 26 or orthoquartzite, may indicate a non-local origin for (at least some of) these raw materials. Information on actual or possible source areas is scarce. However, FRMG 5a appears to be quite similar to chert type #7 of 'Ain Abu Nukhayla (Henry 2014: 83; Henry *et al.* 2014: table 11.1, fig. 11.1). Primary source areas of #7 are reported by Henry around Jabal Qalkhan, associated there with URC layers (Henry 2014: 8). Primary source areas of pink-purple cherts (FRMG 25) are known around Amman and Madaba (Rollefson *et al.* 2007; *pers. obs.*) and have been found in ASL-layers near Ras en-Naqb (Henry *et al.* 2014). FRMG 26 represents the chert type which was processed at Wadi Abu Tulayha and might be characteristic of parts of the western Jafr Basin. Sources of orthoquartzite were reported from Ras en-Naqb, where orthoquartzite pebbles are assumed to be derived from the DI Formation (Wilke *et al.* 2007).

Early Neolithic chert procurement sites

Prehistoric lithic artefact scatters are often found during surveys associated with Eocene chert outcrops. As far as can be seen, these sites represent various periods starting with the Palaeolithic and continuing until at least the Chalcolithic/EBA periods. Evidence of Neolithic raw material procurement has been identified only at Jabal Jiththa and is reported from Jabal Abu al-Idham (Muheisen *et al.* 2004: 135) as well as from Har Gevim (Gopher & Barkai 2011).

Jabal Jiththa
At Jabal Jiththa a large testing site was identified in 2003 (Muheisen *et al.* 2004). Although this site has been heavily damaged by a modern limestone quarry, there is still a large amount of knapping waste scattered on the surface north of a small natural pool, Braq al-Jiththa. These knapping products consist of tested raw material chunks, initial platform spalls, platform trimming flakes and one unfinished celt/adze (Muheisen *et al.* 2004; Purschwitz 2017: 63, table 20; see also Purschwitz 2013 for illustrations). The raw material used in these products is overwhelmingly tabular chert of FRMG 2, with smaller amounts of chert belonging to FRMG 1, both of which can be found abundantly as chunks within the Pleistocene lake sediments. The choice of raw material and the techno-typological features of these knapping products strongly correlate with the initial stages of bidirectional blade core preparation at nearby late PPNB Basta (Gebel 1996; Purschwitz 2017); it is very likely that Jiththa was one of the procurement areas for these raw materials (cf. Muheisen *et al.* 2004).

An intensified survey around Jabal Jiththa revealed a second surface scatter of bidirectional blade production (Purschwitz 2013, 2017: table 21). Some 800m to the north of Braq al-Jiththa at Wadi al-Hassiya, by-products of bidirectional blade core preparation (platform trimming flakes, initial platform spalls) were found associated with products of core reduction; namely, exhausted cores and core tablets. These findings include evidence of both early and later stages of the bidirectional *chaîne opératoire* used for blade production.

Jabal Abu al-Idham
Muheisen *et al.* (2004: 135) report numerous lithic surface scatters observed while visiting the Jabal Abu al-Idham area. Among those scatters, production waste of bidirectional core reduction (exclusively FRMG 1) was found, which correlated to the mega-blade reduction sequence of late PPNB Basta (Gebel 1996; Barzilai 2010: 130; Purschwitz 2017: 216–222).

Har Gevim
The chert quarry complex at Har Gevim is situated some 60km south of the Dead Sea on the western slopes of the Wadi Araba (Gopher & Barkai 2011) (**Fig. 3**). The entire plateau, which measures some 300 by 150m, is covered by piles of limestone detritus, often occurring around a small depression. Gopher and Barkai (2011: 3) estimate the number of quarry pits as between 500 and 600. Two layers of nodular to tabular cherts were exploited, which Gopher and Barkai (2011: 3) have assigned to the Eocene Avedat-Group (most likely the Mor, Nizzana and Horesha-Formation, cf. Baer *et al.* 2014). Surface scatters of lithic artefacts such as bidirectional cores and core preparation debitage provide evidence of a PPNB-use episode at Har Gevim. However, which FRMG (if any) were available and procured at Har Gevim is unclear.

Summary

Most of the FRMG found among the five early Neolithic sites of Ail 4, Beidha, Ba'ja, Basta and Shkârat Msaied were identified during survey in their primary geological settings. The raw material survey indicates that the suitable chert raw material in the Greater Petra Region was predominantly created among two geological formations; namely, the Campanian ASL formation and the Eocene URC formation. Geological maps of the eastern and western sides of the Rift Valley show that both formations are unequally distributed and unevenly exposed (**Figs 3–4**). In the

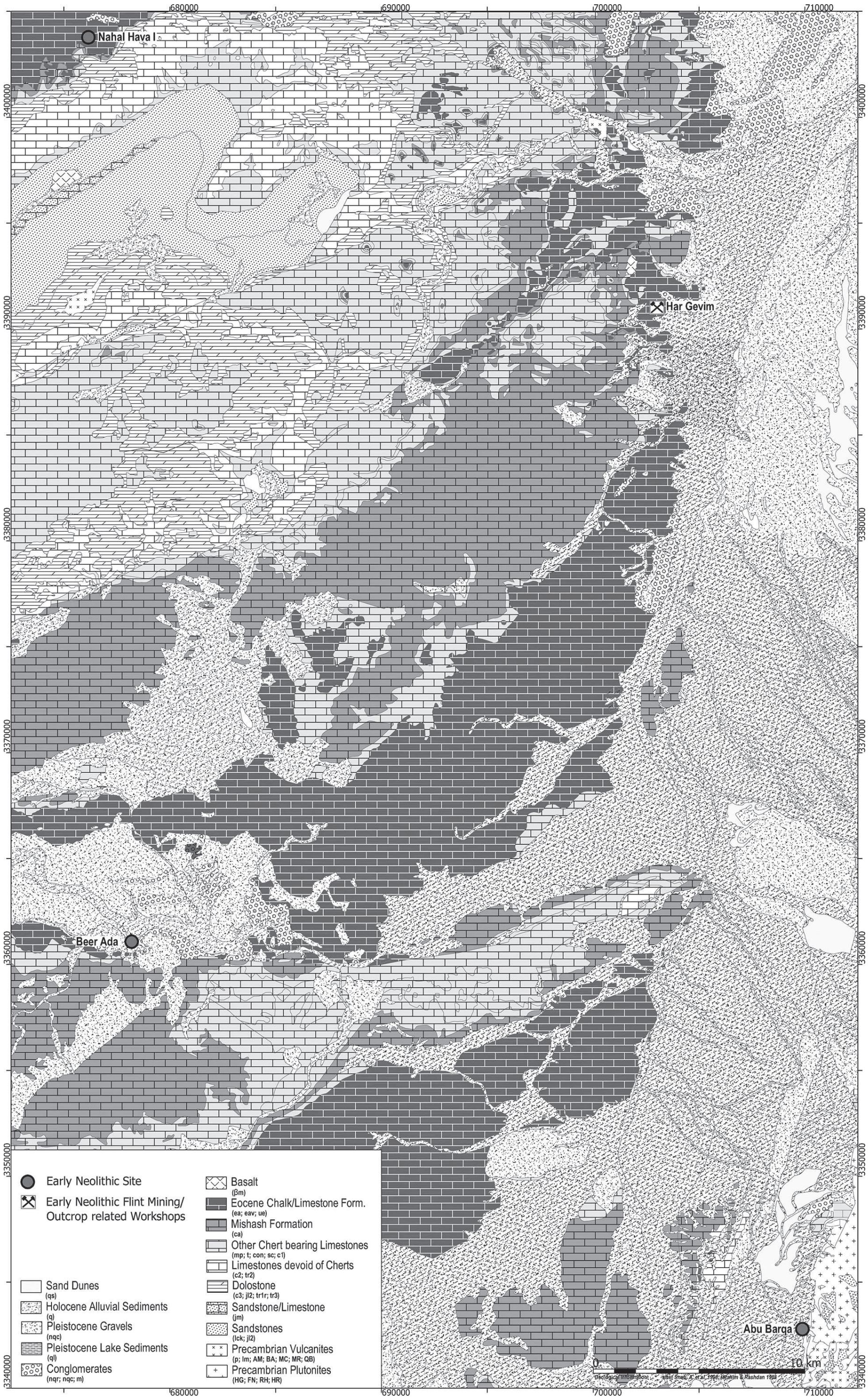

Figure 3. Simplified geological map of the eastern Negev and western Wadi Araba with marking of potentially flint-bearing geological formations (geological information after Sneh et al. 1998)

Greater Petra Region along the eastern side of the rift the exposed Campanian ASL layers are concentrated at the limestone escarpment, while the Eocene URC layers are predominantly exposed in the Jordanian Highlands and Ma'an Plateau further east. However, small relicts of both formations are to be found in the eastern Araba.

The survey showed a high correlation between Chert Raw Material Groups (FRMG) established archaeologically and attested geological origin (**Table 3**). This makes the FRMG-system a suitable tool for predictive modelling of chert raw material source areas in the Greater Petra Region. Additionally, there appears to be some correlation between FRMG

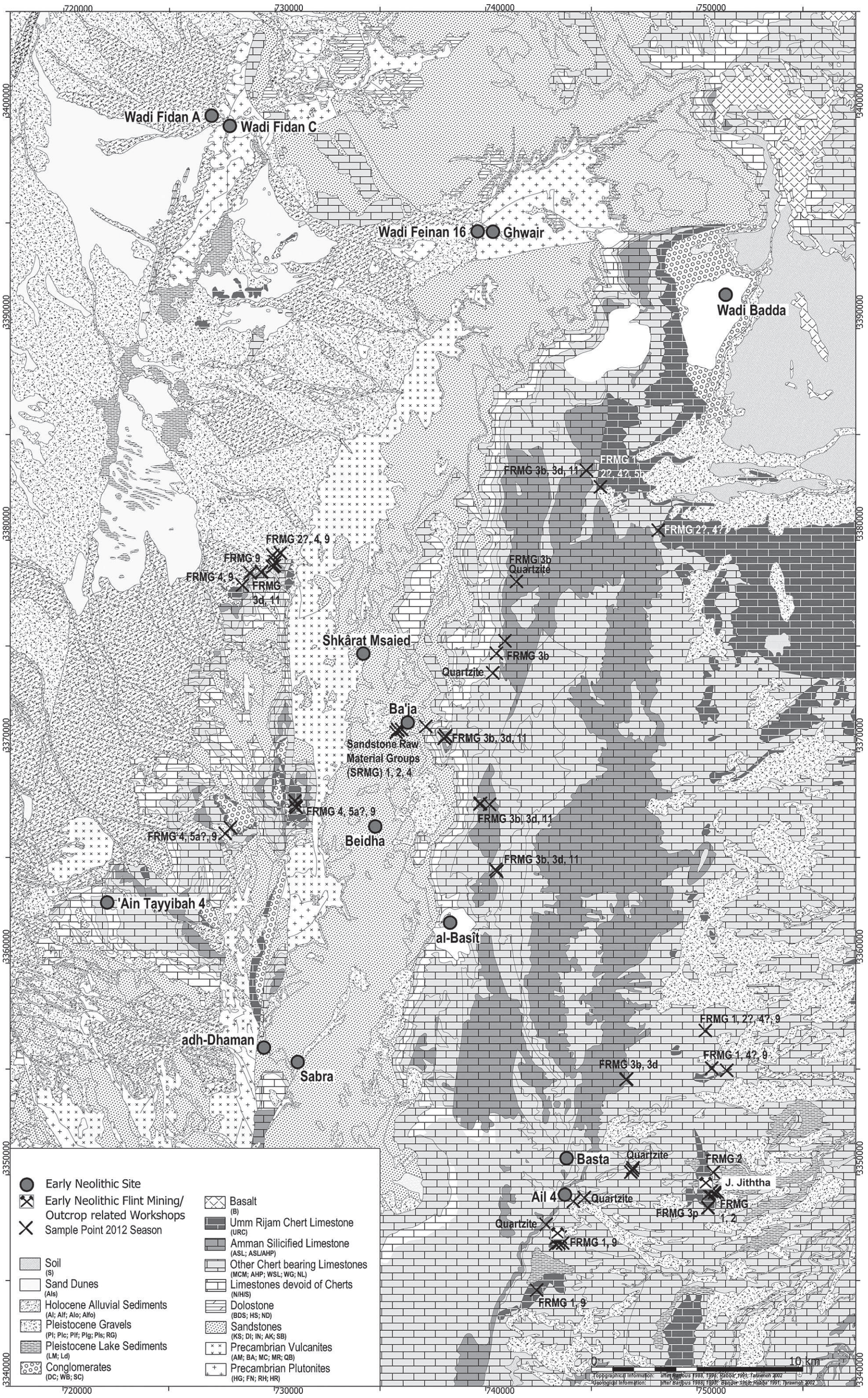

Figure 4. Simplified geological map of the Greater Petra Region with marking of potential and attested flint-bearing geological formations (geological information: Bender 1968; Barjous 1988, 1995; Rabb'a 1991; Tarawneh 2002)

features, such as cortex types, shapes of chert bodies, chert matrix (texture and inclusions) and age of chert formation, which may help to anticipate the possible geological origins of unidentified FRMG or at least to make some layers less likely. However, these results are only valid for the Greater Petra Region and are not necessarily applicable to adjacent regions. This is the case for the western side of the Rift Valley, particularly in the adjacent eastern Negev. This region was set apart, in terms of its geological formation, during

Formation	Location	FRMG 1	FRMG2	FRMG 3B	FRNMG 3D	FRMG 3G	FRMG 3P	FRMG 4	FRMG 5A	FRMG 5B	FRMG 6	FRMG 7	FRMG 8	FRMG 9	FRMG 10	FRMG 11	FRMG 25	FRMG 26	Quartzite	Ortoquarzite
Ld	(12) Jabal Jiththa	∘	○																	
URC	(1) ash-Shobak	●	?					?		•										
	(2) Wadi Namela / Jabal az-Zabda		?					●						●						
	(6) Jabal Abu Sawwan	?	?					○	?					○						
	(8) Jabal Abu Diyya	●	?					?						●						
	(9) Jabal at-Tahuna	●			∘			?						●	?				∘	
	(12) Jabal Jiththa	•					●													
	(15) Jabal Abu al-Idham	●												?						
	(WAT) Wadi Abu Tulayha (NW-Jafr Basin)																	●		
MCM	No flints or other related raw materials attested																			
AHP	(11) Road between Basta and Jabal Jiththa																		○	
	(13) Ail																		○	
	(14) Rujm as-Sadaqa																		○	
ASL/ AHP	(3) Umm Sawwana			●									●						○	
	(4) Jabal Umm Sawwana			●									●						○	
ASL	(1) ash-Shobak			●	●								●			○				
	(2) Wadi Namela / Jabal az-Zabda				○											?				
	(5) al-Heleina / al-Hisha			●	●								●							
	(7) Jabal Marajim			●	●								●		∘	∘			∘	
	(10) Road between Bir Abu Danna and Jabal at-Tahuna			●	●								●							
	(13) Ail			●	●								●							
	(14) Rujm as-Sadaqa			●																
WG	Few flints (poor quality, no related FRMG identified)																			
WSL	No flints found during survey																			
F/H/S	No flints attested																			
NL	Few flints (poor quality, no related FRMG identified)																			

	frequent	rare
primary	●	•
secondary	○	∘

Table 3. Surveyed geological formations and attested Flint Raw Material Groups (FRMG)

the Dead Sea Transform by more than 107km from the Greater Petra Region. The milieu of deposition, an important contributor to chert formation, may have been different and might have resulted in macroscopically different chert types or FRMG than those found in the Greater Petra Region. The use of Negev chert at Greater Petra Region sites during some prehistoric periods, including the early Neolithic, is indicated by the presence of large chert quarries on the western side of the Wadi Araba.

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