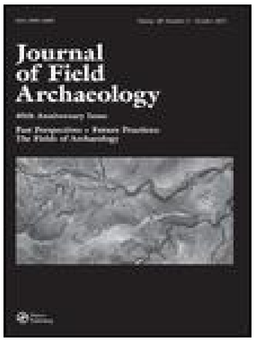

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New Excavations at Border Cave, KwaZulu-Natal, South Africa

Lucinda R. Backwell [a,b], Francesco d'Errico [c,d], William E. Banks [c], Paloma de la Peña [a], Christine Sievers [a], Dominic Stratford [a], Sandra J. Lennox [a], Marine Wojcieszak [a], Emese M. Bordy [e], Justin Bradfield [a], and Lyn Wadley [a]

[a]University of the Witwatersrand, Johannesburg, South Africa; [b]Instituto Superior de Estudios Sociales (ISES-CONICET), San Miguel de Tucumán, Argentina; [c]Université de Bordeaux and C.N.R.S., France; [d]University of Bergen, Bergen, Norway; [e]University of Cape Town, Cape Town, South Africa

ABSTRACT
New excavations at Border Cave use high-resolution techniques, including FT-IR, for sediment samples and thin sections of micromorphology blocks from stratigraphy. These show that sediments have different moisture regimes, both spatially and chronologically. The site preserves desiccated grass bedding in multiple layers and they, along with seeds, rhizomes, and charcoal, provide a profile of palaeo-vegetation through time. A bushveld vegetation community is implied before 100,000 years ago. The density of lithics varies considerably through time, with high frequencies occurring before 100,000 years ago where a putative MSA 1/Pietersburg Industry was recovered. The highest percentage frequencies of blades and blade fragments were found here. In Members 1 BS and 1 WA, called Early Later Stone Age by Beaumont, we recovered large flakes from multifacial cores. Local rhyolite was the most common rock used for making stone tools, but siliceous minerals were popular in the upper members.

KEYWORDS
Middle Stone Age; Later Stone Age; geoarchaeology; archaeobotanical remains; lithic industry

Introduction

We summarize the first results of new field work conducted between 2015 and 2017 at Border Cave, KwaZulu-Natal, South Africa, under the direction of Lucinda Backwell, Lyn Wadley, and Francesco d'Errico. Multiple reasons justify new excavation at this site. Border Cave is the only African site with a dated sedimentary sequence covering a time span of 250,000 years (250 ka) that has yielded Middle Stone Age (MSA) human remains and exceptionally well-preserved organic material, and that also records the first emergence of key cultural innovations. Despite numerous past excavations and analyses, a number of questions persist concerning the site's sedimentary formation, its chronology, and the significance of the archaeological remains from the numerous layers comprising the long cultural sequence. Intact grass bedding layers, dated to between 30 and 70 kya, were only briefly mentioned by previous excavators. These remarkable features present challenges in both the field and the laboratory and require unique excavation and sampling strategies. With a focus on relatively small excavation samples and high-resolution techniques, the principal aims of the new campaign are primarily to reassess the stratigraphic context of the sedimentary and cultural sequence, gain insights into site formation processes, conduct paleoenvironmental and palaeobotanical analyses, identify cultural trends within a secure chronological framework, and when appropriate, document the emergence of cultural innovations. Although the lithic sequence has previously been studied (Beaumont 1978; Villa et al. 2012), Beaumont's analysis did not follow the *chaîne opératoire* approach and Villa and colleagues' technological analysis was restricted to the youngest layers (the Early Later Stone Age). We are interested in characterizing the whole sequence from a technological perspective, in particular the earliest MSA in Member 4 WA and older members where there is high lithic density. Furthermore, Beaumont's excavation methods did not enable spatial studies; we hope, ultimately, to analyze lithics in their site contexts, so that they can be related to spatial features such as fireplaces and bedding areas.

Border Cave is a large, semi-circular rock shelter approximately 50 m wide and 35 m long. It is situated 82 km west of the Indian Ocean in the rugged southern Lebombo Mountains of northern KwaZulu-Natal, near the village of Nkungwini, close to the Swaziland (eSwatini) border and about 5 km east of the Nsoko settlement (FIGURE 1). It is at an altitude of 600 masl on a west-facing cliff that ascends to 678 masl and descends steeply to Swaziland lowveld at 100 masl. The Ngwavuma River is 2 km south of the site, in the lowveld. The diverse topography influences precipitation and the Lebombo Mountains cause a rain shadow on the lowveld where the mean annual precipitation is 200–600 mm per annum (Mucina and Rutherford 2006). The mountains experience frequent morning mists and rainfall averages 781 mm per annum, varying between 550–1000 mm. Rain falls mainly in summer, and winter droughts have been a frequent occurrence in the recent past. The mean annual soil moisture stress (MASMS, the percentage days per annum when evaporative demand is more than double the soil moisture supply) is 74% (Mucina and Rutherford 2006: 490). It is influenced by the high summer temperatures and warm mean annual temperature (20.5°C). Frost is rare.

Geology

Border Cave has a geological context that is unusual among archaeological sites in South Africa. The cave formed in the Lower Jurassic (182.1 ± 2.9 mya) (Riley et al. 2004) felsic extrusive rocks of the Jozini Formation (Lebombo Group),

CONTACT Lyn Wadley Lyn.Wadley@wits.ac.za Evolutionary Studies Institute, University of the Witwatersrand, PO WITS 2050, South Africa
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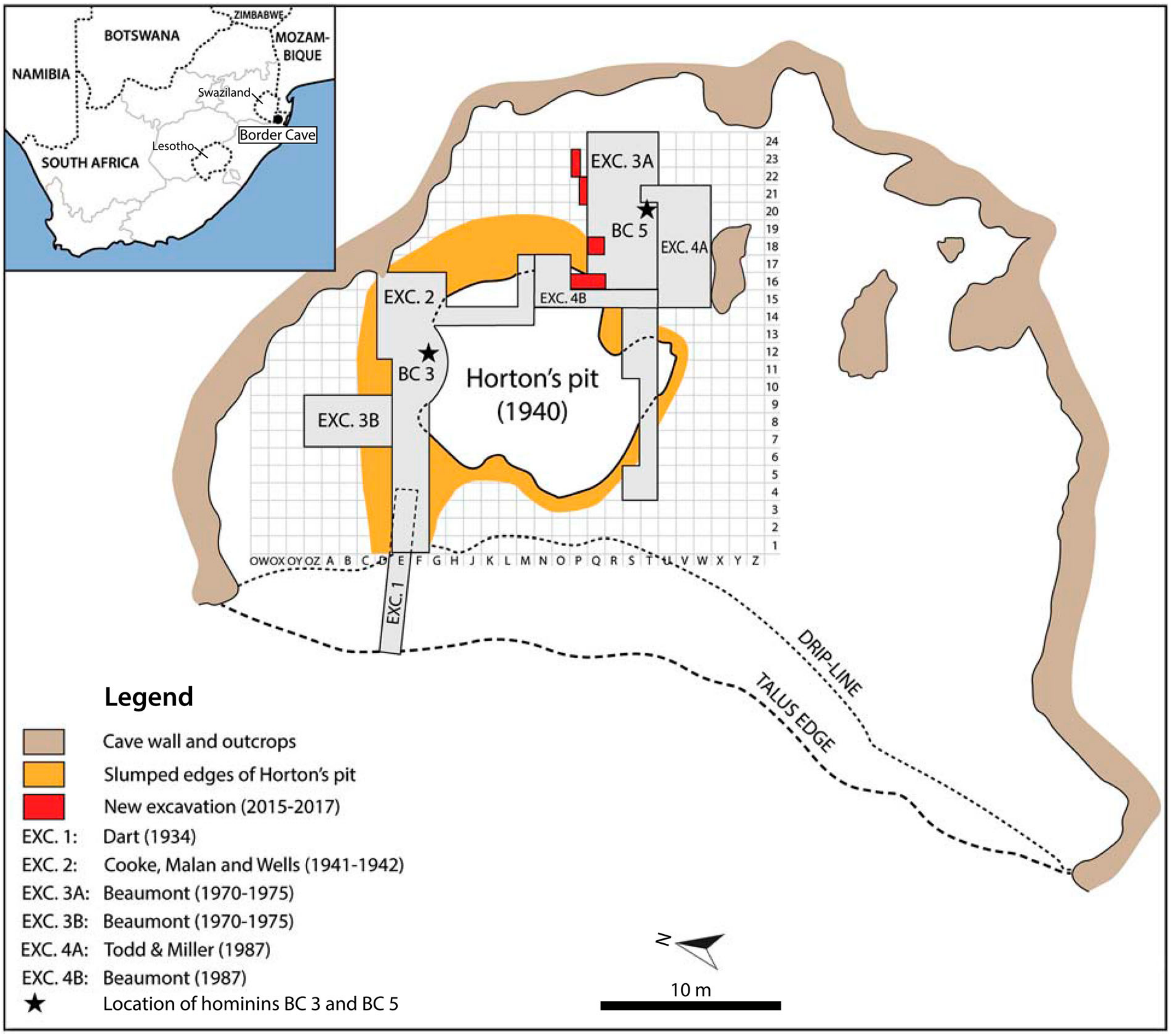

Figure 1. Location of Border Cave and a plan of the site marking the position of the various excavations from 1934 to 2017.

which built most of the Lebombo Mountain in the study area. This 5 km thick succession of rhyolitic lava flows is overall more resistant to erosion than the surrounding pre-volcanic rocks from which it is separated by a prominent escarpment (Cleverly 1977). Differential weathering within the individual rhyolitic flows (that average 200 m in thickness), caused by the variation in their volcanic textures, assists in the regional mapping of the flows (Cleverly 1977; Saggerson and Bristow 1983). Two volcaniclastic facies of the Jozini Formation can be identified in the cave, and these are described here as clast- and matrix-supported breccias (SUPPLEMENTAL MATERIAL 1). The clast-supported breccia facies dominates the roof and sides of the cave and is characterized as a very poorly sorted, ungraded, strongly lithified, massive breccia that has weakly to moderately defined, thickly to very thickly bedded layers that vary in thickness between 0.3 m and > 1 m (SUPPLEMENTAL MATERIAL 1). The bed continuity is moderate; no layer can be traced for more than 10 m. Clasts within this breccia facies are pebble to large boulder size, dense, very angular, poorly-sorted rhyolite fragments as well as thinly-bedded and cross-bedded sandstone blocks that range in size from boulders to megaclasts with diameters > 4 m. Between the clasts, a massive, mostly microcrystalline, and occasionally very fine sandy matrix is apparent.

The matrix-supported breccia facies is only exposed along the southern wall of the shelter (SUPPLEMENTAL MATERIAL 1). This ungraded, massive volcaniclastic breccia comprises fragments of rhyolite within a matrix of medium-grained, highly porous, silt- and clay-rich sandstone. It is tentatively proposed that Border Cave formed because of differential weathering of these two volcaniclastic deposits, of which the clast-supported breccia has been less susceptible to weathering than the more friable, porous matrix-supported breccia. Furthermore, exposed blocks of sandstone within the clast-supported volcaniclastic breccia may also have been subjected to preferential weathering. Cave sediments that are not anthropogenic probably originate primarily from the physical weathering of the matrix-supported volcaniclastic breccia, which was probably more widely distributed in the cave in the past than is currently the case. This would explain the presence of medium-grained sand and roof spall made of rhyolite fragments (SUPPLEMENTAL MATERIAL 1) in the excavated sediments. Additional sources of the cave sediments may be abiotic (aeolian grains) given that occasional gusts of wind enter the cave, and biotic (e.g., guano) inferred from present-day occupation of the cave by bats, and to a lesser extent birds. Two catch trays were set up in 2016, one to monitor the rate of weathering of the volcaniclastic breccias, and the other to document bat guano accumulation in the cave. Data gathered from these trays should help us to understand better the various contributions of abiotic and biotic sources to the composition of the cave sediments.

Modern vegetation

Marked differences in elevation, soils, and moisture availability have produced a mosaic of vegetation types within 5 km of Border Cave (Butzer et al. 1978). The area lies within the Maputoland Centre of Endemism, a biodiversity hotspot that has many endemics and as such, is an important focus of present and past botanical study. Border Cave is situated such that its inhabitants could have taken advantage of lowveld and riverine vegetation (in what is now Swaziland) as well as the diverse habitats of the Lebombo Mountains at 600–700 masl. The Lebombo Summit Sourveld (SVI 17) and Northern (SVI 15) and Southern (SVI 16) Lebombo Bushveld (Mucina and Rutherford 2006: 500–502) vegetation regions occur near Border Cave. In the Southern Lebombo Bushveld, thickets of *Androstachys johnsonii* (Lebombo ironwood) may be seen, and the open bushveld is dominated by *Acacia* and *Combretum* spp. and *Olea europaea* subsp. *africana,* while other important taxa include *Atalaya alata, Bridelia cathartica, Commiphora harveyii, Croton gratissimus, Diospyros dichrophylla, Encephalartos lebomboensis, Erythroxylum emarginatum, Euphorbia tirucalli, Manilkara concolor, Peltophorum africanum, Pterocarpus rotundifolius, Strychnos gerradii, Teclea gerradii, Turraea floribunda, Vepris reflexa,* and *Vitex obovata* subsp. *obovata* (Mucina and Rutherford 2006: 502). In undisturbed areas, *Themeda triandra* is the dominant grass, but *Brachiaria* sp., *Digitaria* sp., *Enneapogon* sp., *Panicum* spp., and *Trachypogon* sp. are also present. The Lebombo Summit Sourveld (which is sour grassland) occurs on ridge plateaus and sloping flanks and it has open, tall, sour, wiry grasslands with low bushes such as *Diospyros dichrophylla* and *Grewia monticola,* and solitary trees like *Acacia caffra* (Mucina and Rutherford 2006: 502). The Gwaliweni Forest borders this zone and although it now covers only 500 hectares, it may once have been of greater extent in the Lebombo (Moll 1977).

Anderson's (1978) botanical survey of the area, based on map grids 2731 BBBD, 2732 AAAC, and 2731 BBBB, recorded the dominant woody taxa in the area as: *Acacia* spp., *Canthium* spp., *Combretum kraussii*, *Dichrostachys cinerea, Diospyros dichrophylla, Eretia rigida, Euclea divinorum, Euphorbia tirucalli, Maytenus* spp., *Spirostachys africana, Strychnos henningsii,* and *Vitex wilmsii.* A new survey made above the cave confirms the presence of several of the taxa recorded in other surveys and adds some new ones (TABLE 1).

Table 1. Preliminary survey of modern woody taxa in the Border Cave area (conducted March 2016, May 2017).

Scientific name	Common name	Family
Acalypha glabrata	forest false-nettle	Euphorbiaceae
Acokanthera rotundata	round-leaf poison-bush	Apocynaceae
Albizia sp.	Albizia	Mimosaceae
Albizia xanthoxylum	Albizia	Mimosaceae
Atalaya alata	Lebombo krantz-ash	Sapindaceae
Canthium ciliatum	hairy turkey-berry	Rubiaceae
Cassipourea swaziensis	Swazi onionwood	Rhizophoraceae
Chaetacme aristata	thorny-elm	Celtidaceae
Coddia rudis	small bone-apple	Rubiaceae
Combretum apiculatum	red bushwillow	Combretaceae
Combretum cf. *microphyllum*	flame climbing bushwillow	Combretaceae
Combretum molle	velvet bushwillow	Combretaceae
Cussonia spicata	cabbage tree	Araliaceae
Diospyros dicrophylla	poison star-apple	Ebenaceae
Dichrostachys cinerea	sickle-bush	Mimosaceae
Dombeya rotundifolia	wild-pear	Pentapetaceae
Ehretia rigida	puzzle-bush	Boraginaceae
Ekebergia capensis	Cape-ash	Meliaceae
Encephalartos lebomboensis	Lebombo cycad	Zamiaceae
Euclea natalensis	hairy guarri	Ebenaceae
Euclea daphnoides	white-stem guarri	Ebenaceae
Eugenia natalitia	forest myrtle	Myrtaceae
Euphorbia tirucalli	rubber euphorbia	Euphorbiaceae
Ficus sycomorus	sycomore fig	Moraceae
Ficus sur	broom-cluster fig	Moraceae
Galpinia transvaalica	wild pride of India	Lythraceae
Gymnosporia buxifolia	common spikethorn	Celastraceae
Harpephyllum caffrum	wild-plum	Anacardiaceae
Lannea antiscorbutica	sand false-marula	Anacardiaceae
Maytenus undata	koko-tree	Celastraceae
Mystroxylon aethiopicum	kooboo-berry	Celastraceae
Ochna serrulata	carnival ochna	Ochnaceae
Ozoroa engleri	weeping resin-tree	Anacardiaceae
Ozoroa sphaerocarpa	currant resin-tree	Anacardiaceae
Pachypodium saundersii	kudu lily	Apocynaceae
Rapanea melanophloeos	Cape-beech	Myrsinaceae
Searsia chirendensis	red currant	Anacardiaceae
Searsia dentata	nana-berry	Anacardiaceae
Searsia leptodictya	mountain karee	Anacardiaceae
Searsia rehmanniana	blunt-leaf crow-berry	Anacardiaceae
Sideroxylon inerme	white-milkwood	Sapotaceae
Spirostachys africana	tamboti	Euphorbiaceae
Tarchonanthus parvicapitulatus	small-head camphor-bush	Asteraceae
Tarchonanthus trilobus var. *galpinii*	trident camphor-bush	Asteraceae
Tricalysia delagoensis	Tonga jackal-coffee	Rubiaceae
Vepris lanceolata	white-ironwood	Rutaceae
Vepris reflexa	bushveld white-ironwood	Rutaceae
Vitex obovata subsp. *wilmsii*	hairy finger-leaf	Lamiaceae

Previous archaeological research at Border Cave

Border Cave has been extensively excavated (FIGURE 1). The first excavation, the results of which are unpublished, was in 1934 by Dart, who dug a narrow east-west trench at the shelter entrance (EXC. 1). In 1940, Horton extracted sediments supposedly for agricultural purposes from a large pit in the middle of the site. Given this stated intention, it is not clear why he left a huge dump of sediment behind. Although enormous damage was done to the site by this unscientific work, it yielded artifacts and human remains that prompted new archaeological investigations. During this third excavation episode (EXC. 2) in 1941 and 1942, Cooke and colleagues (1945) reworked part of Horton's dump and recovered human remains. They also excavated a link between Dart's trench and Horton's pit, and in the process identified a long cultural sequence. Furthermore, associated with an assemblage that is now classified as Howiesons Poort, but which Beaumont initially called Epi-Pietersburg (Beaumont 1978), they discovered an oval pit containing an infant skeleton (BC3) and a perforated *Conus* shell. The shallow grave was in layer 1 RGBS (Cooke et al. 1945) that was later dated by electron spin resonance (ESR) on herbivore teeth to ~74 kya (Grün and Beaumont 2001; Grün et al. 2003; d'Errico and Backwell 2016). This makes the grave the earliest known instance of a human burial associated with a personal ornament.

The fourth excavation (EXC. 3) took place in two different areas (EXC. 3A and 3B) by Beaumont in 11 weeks between 1970 and 1975 (Beaumont 1973, 1978). The fifth excavation (EXC. 4A and 4B), in 1987 by Beaumont and colleagues (Beaumont et al. 1992), considerably expanded EXC. 3A to the south (EXC. 4A) and on its north side (EXC. 4B) it linked 3A to Cooke and colleagues' trench (EXC. 2). The 1987 excavations were designed to collect teeth for ESR dating and also to verify the MSA context of the BC5 human remains that Powell and Beaumont found in 1974 in EXC. 3A while collecting sediment samples. BC5 is a nearly complete adult mandible from the south section, just above the base of undisturbed 3 WA, in the northwest corner of square T20 (FIGURE 1). A fragment of tooth enamel from BC5 (Grün et al. 2003) was directly dated by ESR to 74 ± 4 kya, which is consistent with initial (Grün and Beaumont 2001) and more recent (Grün et al. 2003) ages obtained for the sequence using the same technique on animal tooth enamel. The ESR dates have been published (Grün and Beaumont 2001; Grün et al. 2003), but the excavation itself has not, and we rely on details obtained from Beaumont's MSc dissertation (1978) and a brief heritage agency report to Amafa (Beaumont 1994).

The long cultural sequence was said by Beaumont (1978, 1994; Beaumont et al. 1978, 1992) to include, from oldest to youngest: MSA 1 (sometimes called Pietersburg in the interior of South Africa), MSA 2b (Howiesons Poort, but this was earlier called Epi-Pietersburg by Beaumont), MSA 3 (post-Howiesons Poort), and Early Later Stone Age (ELSA) lithic assemblages. The ELSA layers are overlain by almost sterile sediment topped by Iron Age occupation. The MSA 1/Pietersburg was reported to comprise elongated products, including *Levallois* technique and unifacial and bifacial points, the Howiesons Poort yielded blades and backed tools and the post-Howiesons Poort was characterized by *Levallois* products. A recent study of the ELSA lithics excavated by Beaumont (Villa et al. 2012) confirmed his earlier observation that the lithic industry largely comprises bipolar knapping strategies with scaled pieces and microlithic blanks. The ELSA is much earlier at Border Cave than elsewhere in southern Africa and this enigma remains to be explained.

Based on the chronological sequence, pulses of occupation seem to have occurred between about 200 and 38 kya (TABLE 2). ESR ages imply that MSA 1/Pietersburg industries (in Members 5 WA, 5 BS, 4 WA, 4 BS) accumulated between 227 and 77 kya, the Howiesons Poort (in Members 1 RGBS, 3 WA, 3 BS) between 74 and 60 kya, MSA 3 (post-Howiesons Poort) (in Members 2 WA, 2 BS Lower A, B, C, and 2 BS Upper) between 60 and 39 kya, and ELSA (in Members 1 BS Lower and 1 WA) after about 39 kya. The younger part of the sequence was dated by radiocarbon (Beaumont and Vogel 1972; Beaumont 1980; Vogel et al. 1986; Bird et al. 2003), ESR (Grün and Beaumont 2001; Grün et al. 2003; Millard 2006), and amino acid racemization (Miller and Beaumont 1989; Miller et al. 1999). Forty-two radiocarbon ages are available for the more recent members and these include five recently published ages for the ELSA (d'Errico et al. 2012; Villa et al. 2012) (TABLE 2) and two new ages reported below. Only a representative sample of the radiocarbon ages is reported here.

Table 2. Beaumont's naming system of the Border Cave members together with an abbreviated version of the ^{14}C and Electron Spin Resonance (ESR) dates. For calibrations and methods, see the references provided below. MSA 1 = MSA 1/Pietersburg. MSA 3 = post-Howiesons Poort. HP = Howiesons Poort. ELSA = Early Later Stone Age. * the nine ^{14}C ages for Members 2 WA, 2 BS Lower C and B, ranging from 58 to 48 ka ^{14}C BP, fall outside of the range of the IntCal09 calibration curve. (1: d'Errico et al. 2012; 2: Villa et al. 2012; 3: Bird et al. 2003; 4: Grün and Beaumont 2001; 5: Grün et al. 2003.)

Member	Layer	Industry	Age (kya)	Dating method	Reference
1 BS	UP	ELSA	-	-	-
	Lower A		41.5–24	^{14}C	1
	Lower B		42.3	^{14}C	1, 2, 3
	Lower C		42.6	^{14}C	1, 2, 3
1 WA	UP	ELSA	43	^{14}C	1, 3
	2		-	-	-
	UP	MSA 3	49.0–44.2	^{14}C	3
2 BS	Lower A		49.0–60.0 *	^{14}C	3
	Lower B		-	-	-
	Lower C		-	-	-
2 WA		MSA 3	60 ± 3	ESR	3, 5
3 BS	1	HP	56 ± 2	ESR	4, 5
	2		64 ± 3	ESR	4, 5
	3		72 ± 4	ESR	4, 5
3 WA		HP	64 ± 2	ESR	4, 5
1 RGBS		HP	74 ± 4	ESR	4, 5
4 BS		MSA 1	77 ± 2	ESR	4, 5
4 WA	1	MSA 1	115 ± 8	ESR	4, 5
	6		113 ± 5	ESR	4, 5
	7		168 ± 5	ESR	4, 5
5 BS	2	MSA 1	161 ± 10	ESR	4, 5
	5		144 ± 11	ESR	4, 5
5 WA	1	MSA 1	183 ± 20	ESR	4, 5
	2		227 ± 11	ESR	4, 5

Avery (1992) identified micromammalian remains from Beaumont's excavations and inferred changes in vegetation by using analogies based on the habitat preferences of modern species. Seasonal breeding patterns and required habitats of the species represented in Border Cave imply that the oldest occupations of the site (represented in Members 6 BS, 5 WA, 5 BS and 4 WA [MSA 1/Pietersburg]), where *Mastomys natalensis* (a seasonal breeder) is well-represented, took place under wetter conditions than today, with rainfall seasonally restricted to summer. She suggested that miombo woodland or miombo savanna woodland may have thrived in the Lebombo Mountains at the time. Miombo woodland currently occurs 3 degrees latitude north of the site. She interpreted Member 4 BS conditions as cooler than ones in Member 4 WA (both MSA 1/Pietersburg) and considered that miombo was replaced by Zululand Thornveld (currently in the region) or the type of savanna presently in Mozambique. Thus vegetation seems to have been similar to that of today from Members 4 BS (uppermost MSA 1/Pietersburg) to 2 BS Lower B (post-Howiesons Poort). The coldest period was in 2 WA, and 2 BS Lower A (also post-Howiesons Poort) was thought to be the most arid phase with prominent grassland.

A study of the larger mammals by Klein (1977) from Members 1 GBS (later renamed 4 BS by Beaumont, Miller and Vogel [1992]) through to Member 1 BS (that is, from the youngest MSA 1 assemblage to the Iron Age) suggests that the vegetation mosaic in the area was broadly similar to the one at present, at least from about 77 kya through to the final MSA. This tends to support Avery's environmental conclusions for the period. Nonetheless, Klein thought that Member 1 GBS (4 BS) (uppermost MSA 1/Pietersburg) represented different climatic conditions from today, with more bush than in the grassier conditions of Members 2 WA and 2 BS (post-Howiesons Poort). *Syncerus caffer* (Cape buffalo), *Equus quagga* (plain's zebra), Alcelaphines, and *Potamochoerus porcus* (bushpig), as well as a variety of antelope were present through the sequence in small frequencies (Klein 1977).

Butzer and colleagues (1978: 338) suggest that the alternating frequencies of grazers and browsers through time imply that Member 1 GBS (4 BS) (MSA 1/Pietersburg) had a woodland-savanna habitat mosaic whereas 2 BS Lower, 2 WA (post-Howiesons Poort) and 3 BS Upper (Howiesons Poort) had grassland/savanna habitats.

Butzer interpreted three rock spall horizons in the center of the sequence as *éboulis sec*, implying frost fracturing, while a major soil development at the base of the sequence was interpreted as evidence for wetter conditions, thereby supporting Avery's interpretation of higher rainfall during the period corresponding to Members 5 WA to 4 WA (MSA 1/Pietersburg).

The New Excavations

Excavations were undertaken during a total of 11 weeks in August/September 2015, February/March 2016, and May 2017.

Grid system and excavation strategy

We established a new grid tied into the original datum and this is now mapped with a total station. Cooke and colleagues' 1941 peg markers were easily located because they are recorded as crosses on the roof. Peg 1 is situated at the north wall of the cave near the gated entrance and Peg 2 is on the north-south line, near the drip line, but downslope towards the southern wall of the cave (FIGURE 1, SUPPLEMENTAL MATERIAL 2). Our grid is aligned to Pegs 1 and 2 (coordinates 100N, 100E, and 100Z originate at Peg 2). Our grid does not match the older one perfectly because we use metric instead of imperial measurements (yards). Furthermore, there has been considerable erosion of the original excavation sections, so the squares we are excavating are not whole. Based on preservation and ease of access, we decided to excavate part of the northern face of Beaumont's EXC. 3A and part of the eastern edge of EXC. 4B (FIGURE 1, SUPPLEMENTAL MATERIAL 2). Beaumont's excavation stepped down from the back to the front of the cave and this provides the opportunity for us to sample the entire sequence of Border Cave members without having to excavate each square from surface to bedrock. Our excavations coincide more-or-less with squares P23, P22, P21, P20, and Q18 on the Cooke and colleagues' grid (these squares are on the northern face of EXC. 3A), and with squares P16 and Q16 along the eastern edge of EXC. 4B (FIGURE 1, SUPPLEMENTAL MATERIAL 2). Our grid system changes the name of the east-west P line to N109, the Q line to N108, and the north-south lines from 23 through 16 to E120 through E113. Our excavations are therefore into squares E120, E119, E118, E117, and E113 on line N109, and E115 and E113 on line N108. Squares E120 and E119 are uppermost towards the back of the cave and they have yielded Members 1BS Lower C, 1 WA (ELSA) and 2 BS (post-Howiesons Poort). Squares E118 and E117 in the middle portion of Beaumont's north profile, presently expose Members 2 BS Lower, 2 WA (post-Howiesons Poort), and 3 BS (Howiesons Poort). Square E115 has the base of Member 3 BS at its summit and it has been excavated to 1 RGBS (MSA 1/Pietersburg). Both E113 squares yielded Member 4 BS (about 77 kya) at their summit and they have been excavated into Members 4 WA and 5 BS (MSA 1/Pietersburg), thought to date between about 115 and 160 kya, respectively. Within these newly designated square meters, we conducted excavations within 50 cm squares and according to natural, rather than arbitrary, layers (see below). Consequently, a member usually incorporates many small layers and features, excavated at centimeter–scale. The small stratigraphic layers are listed with their host member in Supplemental Material 3. We have attempted to work within the broad framework of names and numbers used by the previous excavators for Brown Sand (BS) and White Ash (WA) members. Beaumont's handling of the stratigraphy was, however, simpler than ours; he tended to treat the members as layers and he removed large volumes of sediment rapidly. In contrast, we have recognized and separated many small layers and features within each member (FIGURE 2, SUPPLEMENTAL MATERIAL 3, 4). Features, as described earlier, are named first for their member and layer and then their identity. For example: Member 4 WA, Layer White 7, Combustion Feature 1. Our new excavations have thus far sampled all Beaumont's stratigraphic members listed in Table 2, except 6 BS, 5 WA (the oldest MSA 1/Pietersburg) and 1 BS Upper (Iron Age) (FIGURE 2, SUPPLEMENTAL MATERIAL 4). Our layers and all items larger than 2 cm are plotted in three dimensions with a total station.

Sediments and stratigraphy

The Border Cave sedimentary sequence comprises alternating Brown Sand (BS) and White Ash (WA) members and these gave rise to the naming system used by previous excavators. The sediments were first studied in detail by Butzer (Butzer et al. 1978). They formed through a combination of geological and anthropogenic processes. Roof spall and authigenic minerals, including feldspars and plagioclase, are geologically derived; the ash, bone, artifacts, and layered grass bedding (FIGURE 3) represent anthropogenic contributions. The matrix of most sediment, particularly in the Brown Sand members, is dominated by sand-sized particles of fragmented rhyolite that decayed from the rhyolitic host rock with minor contributions of sand deriving from the sandstones incorporated into the host rock. The larger clastic components of the sediments (gravels) are predominantly poorly to moderately sorted angular and irregularly shaped rhyolitic fragments. As observed previously by Butzer, there are clear fluctuations through the sedimentary sequence in the size and abundance of clastic material representing differential erosion or breakdown of the cave's ceiling. The greater density of roof spall inclusions and the stacking of grass bedding towards the back of the cave have resulted in differential sedimentation that caused a pronounced slope of sediments from east to west. At the back wall, the sediments are up to four meters deep, but they are markedly shallower at the front of the cave. Combustion features and grass bedding are the most common anthropogenic features in most WA and BS members (FIGURE 3, SUPPLEMENTAL MATERIAL 4), though the combustion features observable in the BS members are neither as abundant nor as large as is observed in the WA members. Combustion features include small basin-shaped hearths, wider expanses of burning and raked-out areas of ash and charcoal. The first two feature types are often marked by a white ash top, a black or dark brown layer below this, and a basal rubified layer. In some instances, presumably when fires were especially hot, the dark charcoal-rich layer is absent and white or yellowish ash rests directly on orange or reddish-brown sediment. White Ash (WA) members frequently contain complex successions of laterally overlapping, interdigitating combustion features of various sizes. Some of the combustion features comprise burnt bedding layers as was also the case at Sibudu (Goldberg et al. 2009; Wadley et al. 2011). Bedding will be described in more detail later; here it suffices to say that its presence is due to the exceptional organic preservation in parts of the site.

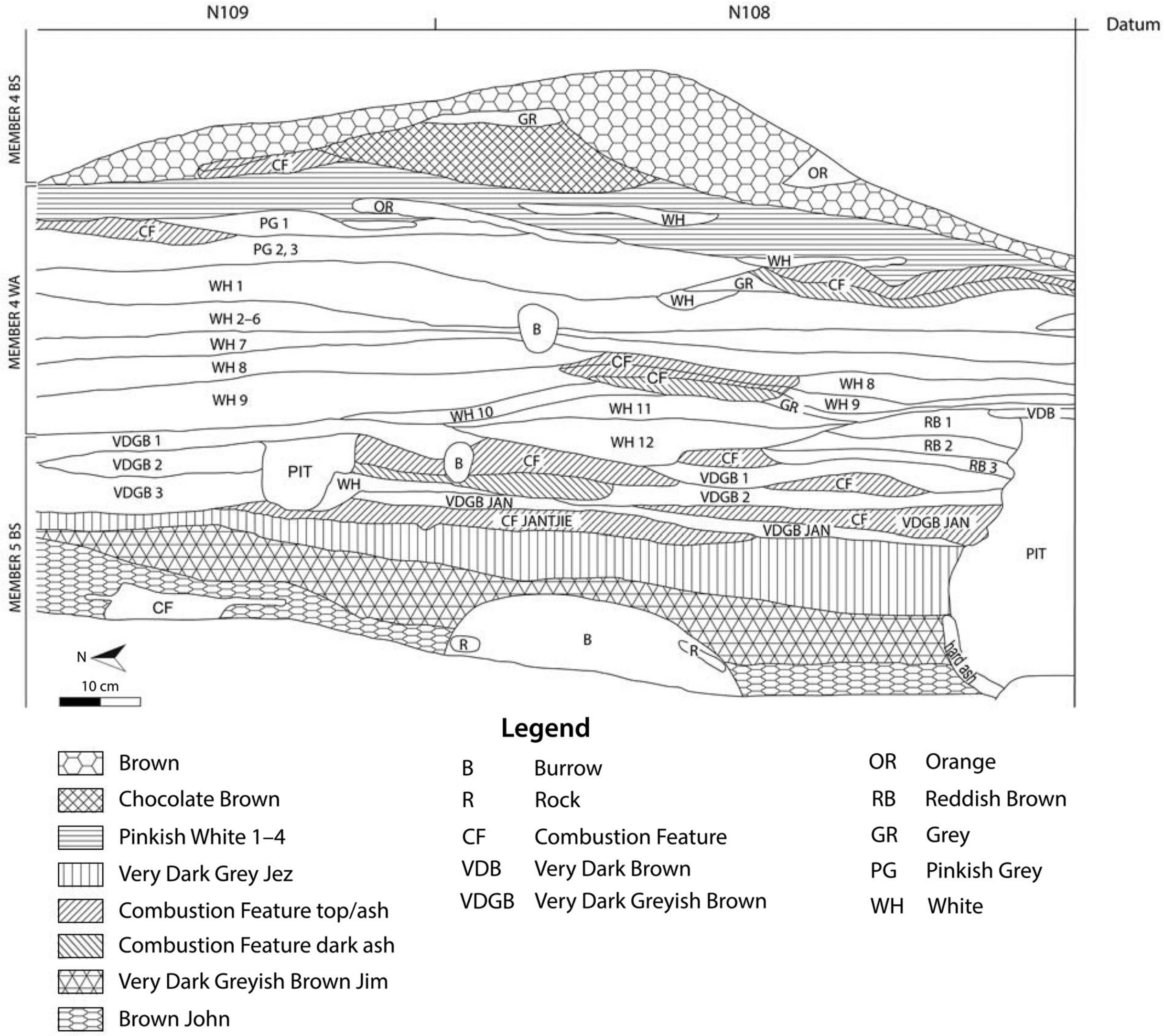

Figure 2. Border Cave, East Profile, Squares N108 E113 and N109 E113. The tops of the squares have been eroded away. Layers Brown, Chocolate Brown, and Dark Brown are in Member 4 BS. Member 4 WA incorporates layers Pinkish White to White 12. Member 5 BS begins in layer Very Dark Greyish Brown.

Stratigraphic integrity and assemblage preservation are not uniform across the site. Butzer and Beaumont both described the cave as very dry and rejected the presence of non-anthropogenically derived erosive processes, suggesting that "occupation accelerated sedimentation rates (probably through reworking of superficial sediment into lenticular cultural deposits) and created disconformities (by mobilizing or deliberately removing sediment). It is probable that no natural, erosional breaks exist in Border Cave" (Butzer et al. 1978: 327). However, in several areas and through several strata there is evidence for repeated erosion caused by low energy water flow in the past. Although not enough deposit has been exposed to understand the broader spatial patterning of the channels or mixed sediments, evidence is found sporadically in restored profiles of Beaumont's trenches and in our new profiles. For example, on the southern face of EXC. 4A, which Todd and Miller excavated in 1987, Member 2 WA (post-Howiesons Poort) sediment is eroded by shallow, superimposed braided channels that probably originated at the back of the cave and flowed northwest, downslope (SUPPLEMENTAL MATERIAL 5). Also, on the exposed eastern face of Horton's Pit, 1 RGBS (Howiesons Poort) is heavily and deeply incised by an erosion channel filled with a mixture of sediments from upslope. Adjacent to Horton's Pit, Square N109 E113 has an older erosion channel that truncates Member 5 BS (MSA 1/Pietersburg). The channels in both these areas would have flowed from the back wall in the east to the westerly cave entrance. Another channel was located on the northwest face of Square N108 E115 and has truncated Members 3 BS, 1RGBS (Howiesons Poort), and 4 BS. Member 3 WA (Howiesons Poort) is missing entirely here perhaps because of the channel, but perhaps because it does not extend over the entire site. It is, for example, not visible in the eastern wall of the Horton pit. The channels lack the layered structure of surrounding sediments and contain a mixture of poorly sorted and poorly organized, fragmented charcoal, stones, and bones (SUPPLEMENTAL MATERIAL 6). Other disturbances to the sediments include rodent and insect burrows (easily identified by their light brown color and homogeneous sediments), trampling, and sedimentary contacts indicative of active slope processes. Though these are difficult to identify when sediment color and texture of adjacent strata are similar, they are most identifiable in clearly laminated WA members where coloration has provided additional capacity for identifying fine-resolution stratigraphic contacts (Butzer et al. 1978). These features are visible in transverse and longitudinal sections through Beaumont's EXC. 3A and 4A. They seem to be most abundant in the

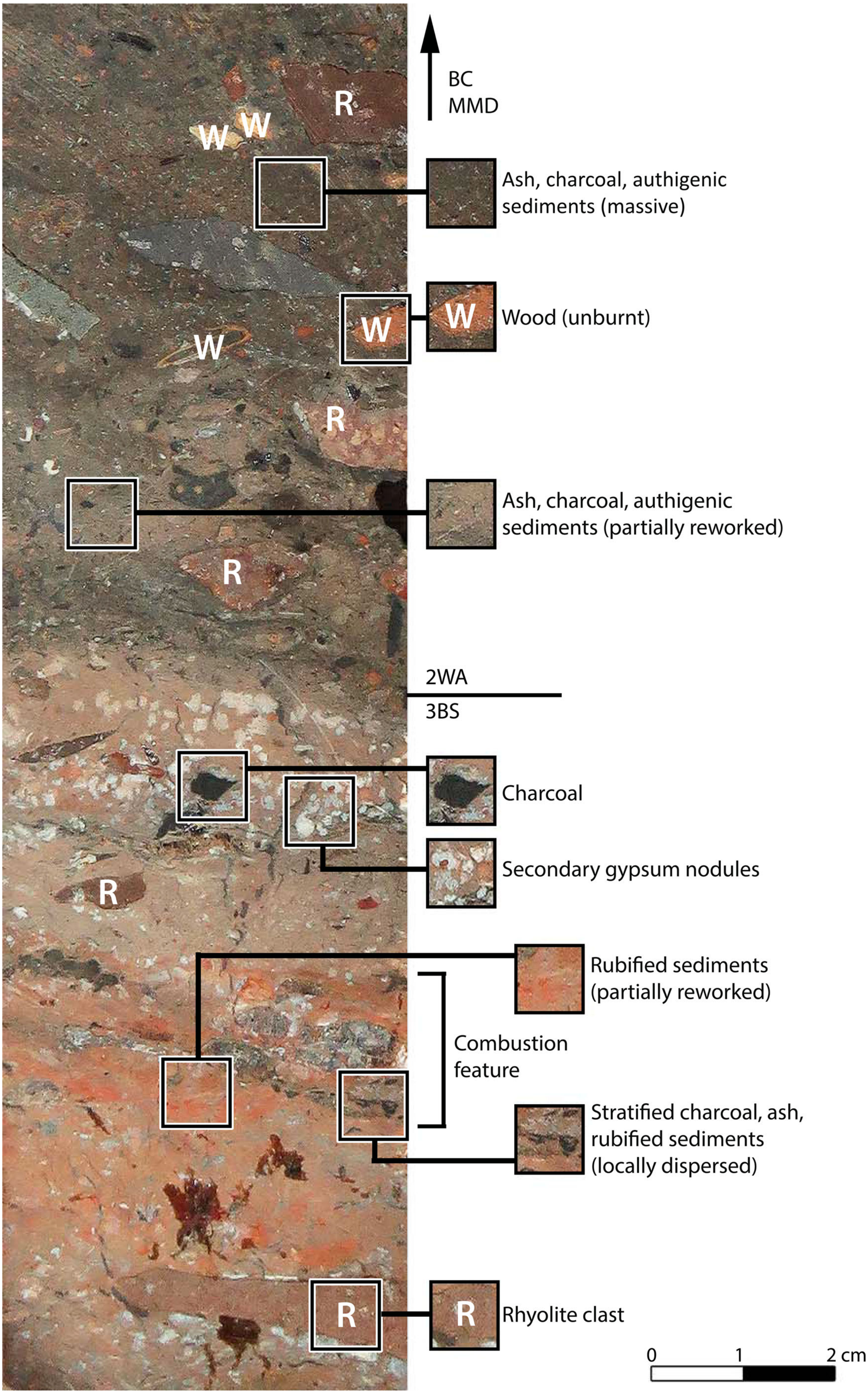

Figure 3. Micromorphology block (MMD) sampling the 2 WA, 3 BS contact taken from the south wall of EXC. 4A (See Supplemental Material 5 for context of sample). The scale bar represents 1 cm increments. In this area, Member 2 WA has been affected by a variety of post-depositional processes and secondary mineral accumulation to a greater extent than the Member 2 WA sediment exposed and excavated in the north wall of EXC. 3A. In the south wall profile, fluid and gravitational processes have affected some of the primary anthropogenic structures in the deposits on a localized scale. We can, however, identify residual punctuated combustion features (as indicated by compacted ash, fragmented but abundant charcoal and rubified sediments) and well preserved layered and compacted organic remains (potentially bedding layers). The contact between Members 2 WA and 3 BS is sharp and well-preserved. This sample demonstrates the potential preservation of anthropogenic features within Brown Sand members. The vegetation (W) comprises wood in various stages of preservation. Secondary gypsum nodules have penetrated the profile after exposure through excavation and have accumulated sporadically laterally and vertically preferentially in ashy areas.

medial portion of the slope exposed along the longitudinal axis in Beaumont's P22 – P19, in the new excavation squares E119, E118, E117. This suggestion supports Grun's chronology (TABLE 2) where time is missing between Members 2 BS and 2 WA (post-Howiesons Poort) and between 4 BS and 4 WA (MSA 1/Pietersburg). Such stratigraphic unconformities imply missing time or truncation events; thus artifacts and other remains in these areas may not be closely associated. Some of the disturbances to strata are anthropogenic rather than geogenic; for example, excavations revealed areas of reworked ash, in which bones and stones are chaotically distributed, suggesting the presence of raked out combustion features.

In situ FT-IR analyses will enable us to add precision to Butzer's earlier observations and our preliminary ones. The FT-IR spectra were acquired by M. Wojcieszak with a portable Bruker Alpha equipped with an Attenuated Total Reflectance (ATR) module. Close contact was made between the sample and a diamond crystal. The spectral resolution used was 4 cm^{-1} and the spectra were acquired with 64 scans between 400 and 4000 cm^{-1}.

The two sediment samples analyzed here from square N108 E113 are examples of what we shall achieve in more detailed ongoing studies and focus on the variation of precipitated calcium compounds in and around a small pit filled with dark brown sediment discovered in Member 4 WA (FIGURE 2, square N108, PIT). They are Member 4 WA - #2349 – feature: Dark Brown Pit (with white nodules) and Member 4 WA - #2367 – layer: White 10 (white ash). FT-IR analysis of the two samples revealed several components commonly found in archaeological cave sediments. The first ATR-FT-IR spectrum (FIGURE 4A) is of white nodules present in the dark brown pit (#2349). It is dominated by gypsum (calcium sulphate). The characteristic IR vibrational bands of gypsum are located at 450, 597, 668, 1005 (shoulder), 1104 (sulphate bands), 1619, 1682 (doublet, bending vibrations of O-H), 3243, 3998, and 3517 (stretching vibrations of O-H) cm^{-1} (Shillito et al. 2009; Chen et al. 2015). Additional weak bands around 877 and 1407 cm^{-1} and a doublet at 780 and 797 cm^{-1} can be respectively attributed to calcite (calcium carbonate) and quartz that are weakly represented (Shillito et al. 2009; Müller et al. 2014). Both gypsum and calcite are arid indicators. Both are soluble when conditions are wet, but calcite is less soluble than gypsum, so the presence of calcite alone may sometimes imply wetter conditions than when gypsum is also present (Schiegl and Conard 2006). Gypsum can originate from several sources, such as the breakdown of organic materials like wood (through time or heat) or bird and bat guano (Schiegl and Conard 2006). Fresh wood-ash is predominantly calcite so the presence of calcite deposits can simply imply that much burning took place. The preliminary results show variation in gypsum and calcite content within and between layers in Members 5 BS, 2 WA and 2 BS (data not shown).

The second spectrum (FIGURE 4B) was recorded on sediment from one of the white layers in Member 4 WA. The strong bands at 875 and 1435 cm^{-1} and the weaker features at 712, 1797, 2514, and 2873 cm^{-1} identify calcite as the major component (Shillito et al. 2009). The bands at 564 and 604 cm^{-1} arise from the apatite phosphates; the last

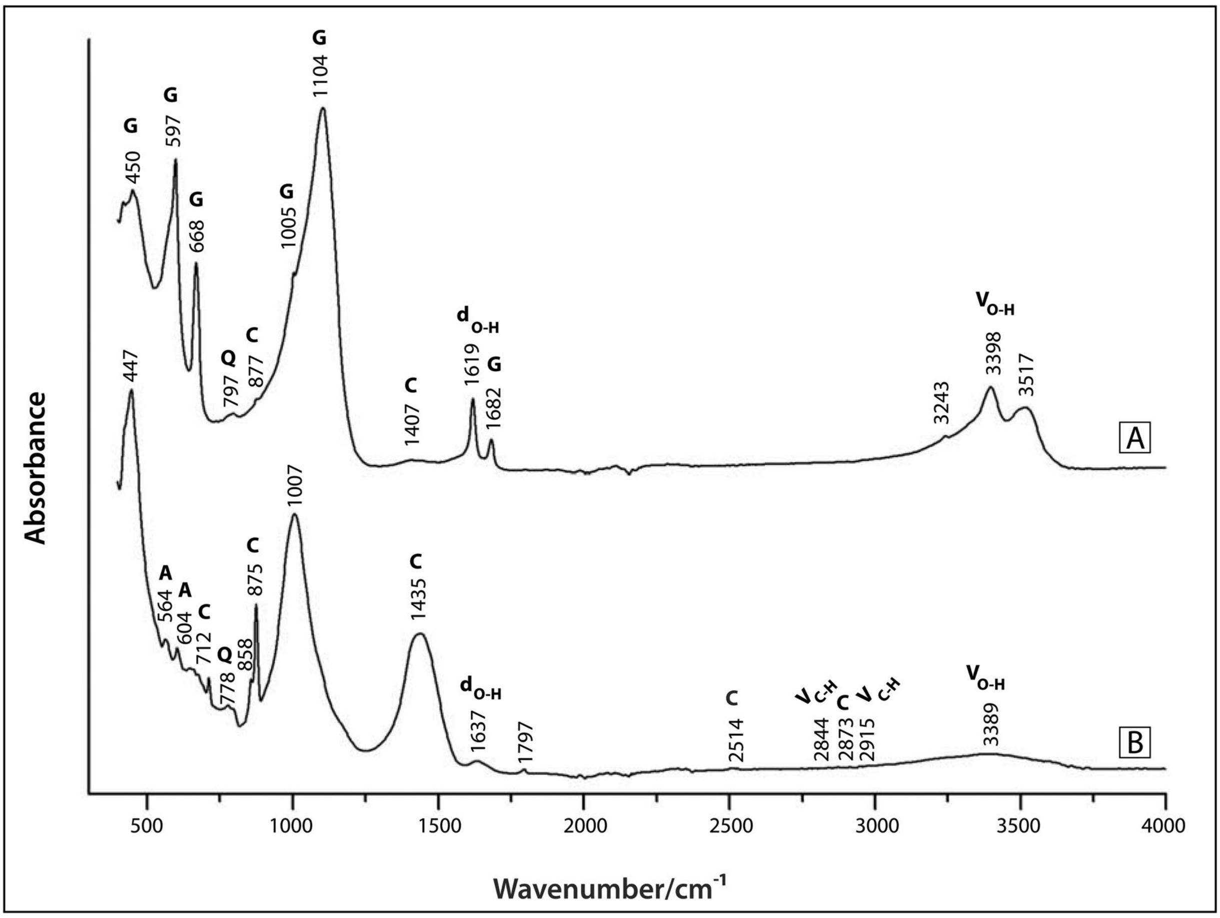

Figure 4. Representative ATR-FT-IR spectra of A) white nodules (gypsum) present in the dark brown pit in Member 4 WA and B) a white layer (calcite) #2367 of Member 4 WA. A = apatite; C = calcite; G = gypsum; Q = quartz; δO-H = O-H bending vibration; vC-H = C-H stretching vibration and vO-H = O-H stretching vibration.

strong apatite phosphate band generally located between 1000 and 1100 cm^{-1} is hidden under the strong and broad band at 1007 cm^{-1}. The latter can also comprise Si-O stretching vibrations from silica minerals such as clay, plagioclase, and feldspar. Some organic matter is detected thanks to the stretching vibrations of C-H at 2844 and 2915 cm^{-1}. The mixture of calcite and apatite can derive from the accumulation of anthropogenic ash deposits (Weiner et al. 2002) and certainly the White Ash members at Border Cave appear to comprise multiple combustion features.

These preliminary results give us confidence that we shall be able to use FT-IR together with other geoarchaeological techniques to get a better understanding of site formation processes at Border Cave.

Lithics

Here we present a preliminary analysis of the lithics from the 2015 and 2016 excavation seasons and a small sample from 2017 (3 BS only [Howiesons Poort]).

In this preliminary analysis the main techno-typological categories are counted by member and layer (core, flake, blade, retouched piece, chunk, fragments, and chips) and distinguished by rock types (FIGURES 5, 6). The principal objective is to have a general count of lithic categories by raw material and to detect the main technological strategies through the sequence. At present our sample is small; thus, it is not possible to determine to what extent the industries named in previous publications (TABLE 2) correspond with the newly excavated material. Thus, the cultural units named here should be seen as preliminary determinations that match Beaumont's nomenclature, but that will not necessarily influence future decisions about cultural designations when a larger sample of lithics has been excavated and analyzed.

This preliminary lithic analysis includes 1218 blanks larger than 2 cm and 3527 chips. The main rock and mineral types knapped at the site are: rhyolite, hornfels, quartzite, basalt, agate, chalcedony, and quartz (only hyaline quartz was present). Beaumont's earlier analysis did not include basalt as a rock type. As can be seen in Figure 5, the most abundant rock type throughout the members is rhyolite. However, in Members 5 BS, 4 WA (MSA 1/Pietersburg), and 2 WA (post-Howiesons Poort), hornfels and basalt gain importance. It is also worth mentioning that quartz only appears at the top of the sequence (2 BS Upper [post-Howiesons Poort] and 1 BS Lower C and 1 WA [ELSA]), and that chalcedony and agate are only prominent in Members 3 BS (Howiesons Poort) and 1 BS Lower C and 1 WA (ELSA). This is completely in accordance with Beaumont's original analysis of rock types (Beaumont 1978: fig. 38).

As a general comment regarding the technological categories, it is noteworthy that the highest percentage frequencies of blades and blade fragments have been found in Member 4 WA (MSA 1/Pietersburg) and to a slightly lesser extent also in 5 BS (MSA 1/Pietersburg) and 2 BS Lower (post-Howiesons Poort), and not in 3 BS (Howiesons Poort), where this would have been expected because the Howiesons Poort is usually a bladelet and blade-rich technology.

Few lithic blanks were recovered from Members 1 BS Lower C and 1 WA (ELSA), where thick bedding units occurred. Nonetheless, a remarkable technological feature in these Members is the presence of big flakes probably from multifacial cores. This is not an entirely new discovery, because Beaumont (1978) noted the presence of "very crude radial prepared cores" and faceted flakes, as an oddity within the industry that he called Early Later Stone Age (ELSA). Our sample of lithics from this industry is still small and therefore it cannot, at this stage, be compared with the large assemblage dominated by bipolar blanks and cores that was analyzed by Beaumont (1978), and later by Villa and colleagues (2012).

For material excavated so far from Members such as 2 BS Lower (post-Howiesons Poort), it is clear that there is a *Levallois* reduction sequence for flakes and blades. Moreover, elongated and pointed *Levallois* blanks are quite frequent and sometimes retouched (FIGURE 7). Besides this, big flakes (over 10 cm in breadth) were produced. In previous Beaumont publications this industry was placed in MSA 3 (post-Howiesons Poort). In Square N108 E115 Member 3 BS (possibly Howiesons Poort) there are several *Levallois* cores (FIGURE 8). Thus far, we have excavated only a small sample of lithics, therefore it is not possible to determine whether *Levallois* technology is chronologically restricted.

Members 5 BS and 4 WA (MSA 1/ Pietersburg) also have *Levallois* reduction strategies for flakes and blades. Furthermore, some of the layers recently excavated in these Members have clear bladelet production, which is contrary to Mason's (1962) expectation that a Pietersburg Industry should have large blade production. In the basal layers of Member 4 WA and in the top ones of Member 5 BS, *Levallois* points are abundant (FIGURE 9), and this might be one of the reasons that the Border Cave MSA 1/Pietersburg was previously compared typologically to the top layers of Cave of Hearths and to Mwulu's Cave in Limpopo (Beaumont 1978).

In Square N108 E115, Member 3 BS (Howiesons Poort) was truncated by a water channel that in part was 50 cm wide. The surfaces of the lithics in the channel are water patinated. The presence of this water channel might explain why Member 3 WA (Howiesons Poort) was not found in this square; however, it was also not visible in the exposed sections of the Horton Pit, so 3 WA may have restricted distribution in the cave (as also noted by Beaumont [1978]).

Members 4 WA (MSA 1/Pietersburg) and 2 BS Lower (post-Howiesons Poort) contain the highest volume density of lithics in the sequence (FIGURE 10). The high volume density in 4 WA supports Beaumont's earlier observations (Beaumont 1978: Fig. 60; Beaumont et al. 1992: 490).

Botanical remains

BEDDING SAMPLES

Multiple layers of exceptionally well-preserved grass and leaf bedding are visible in the exposed sections: in some cases these stretch over more than two meters. Many of these are unburned, while some are partially burned. The uppermost bedding we excavated is from Member 1 BS Lower C. The second was retrieved from 1 WA (ELSA). Older bedding was recovered from 2 BS, 2 WA, and 3 BS, attributed to the post-Howiesons Poort and Howiesons Poort. The 3 BS bedding remains are fragile; some patches are burned, others desiccated. No bedding was found in Members 4 WA or 5 BS (MSA 1/Pietersburg). Often desiccated bedding overlies cemented or partly cemented white ash. While it is not impossible that this super-positioning was fortuitous, people may have deliberately chosen clean, consolidated surfaces on

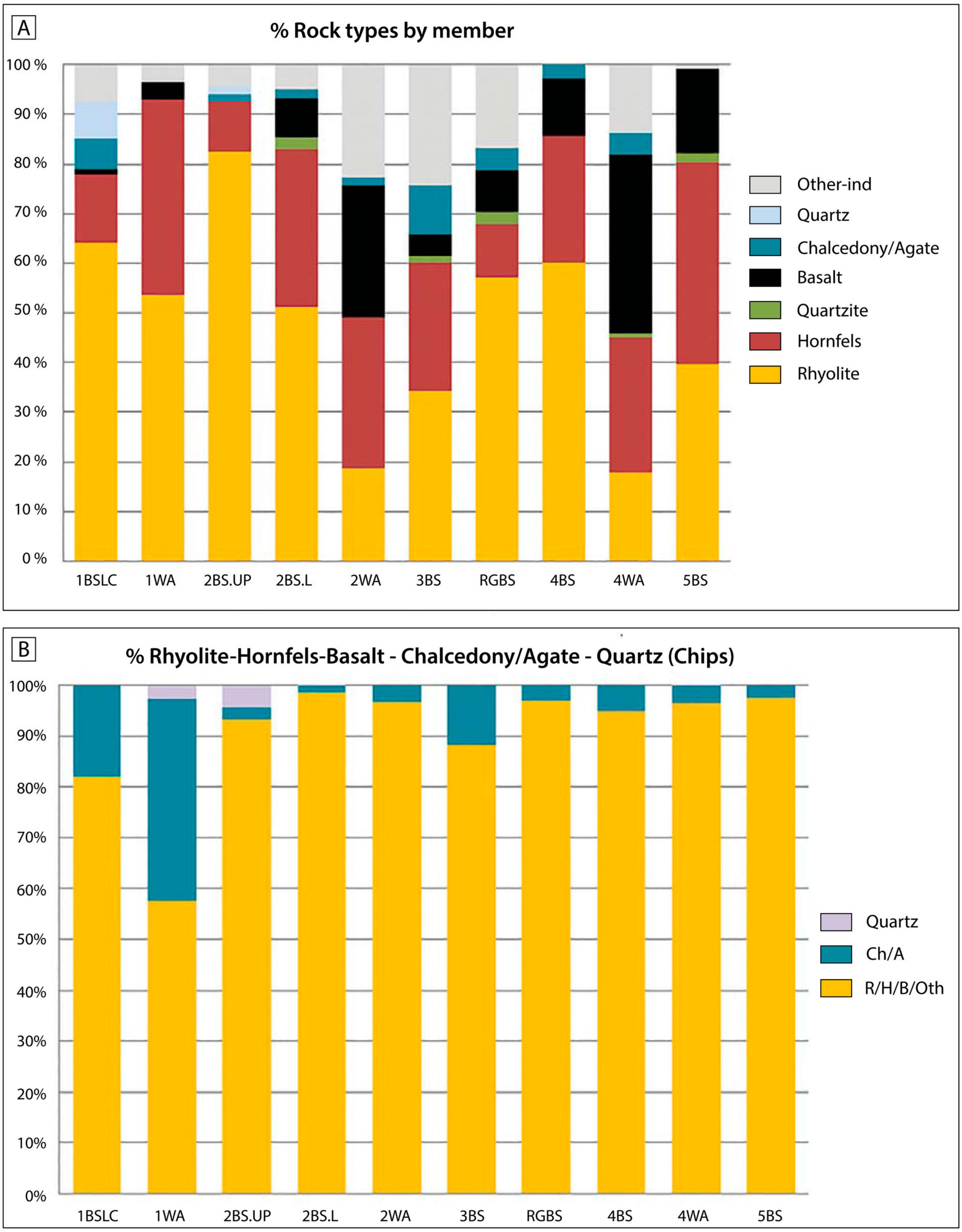

Figure 5. Border Cave percentage frequencies of the main rock and mineral types by Member. A) Pieces larger than 2 cm; and B) pieces smaller than 2 cm (chips).

which to place bedding. Furthermore, ash acts as an insect repellent (Wylie and Speight 2012: 198) and an ashy substrate may have kept bedding relatively pest-free.

Samples of 2 BS and 1 BS bedding were collected for AMS dating in Oxford. The bedding with an EDM reading #796 from square N109, E119, Member 2 BS Upper, produced a date of 43,300 ± 2700 B.P. (OxA-33716), which falls beyond the calibration curve ([50,000]–42,826 CAL B.P.). This bedding was rich in microscopic ochre particles that may have rubbed off human skin or clothing. Sample #742 from square N109 E119, Member 1 BS Lower C, produced a date of 36,700 ± 900 B.P. (OxA-33715) (42,533–39,362 CAL B.P.). The two new radiocarbon ages fit well with the existing radiocarbon chronology for these members.

Sections of bedding were jacketed in gypsum bandages and successfully removed in toto for excavation and analysis in the laboratory (FIGURE 11). They were photographed and excavated in the laboratory using dental picks, tweezers, and squirrel-hair paint brushes, size 0 or 00. Loose material was sieved through 1 mm, 0.5 mm, and 0.25 mm nested geological screens. Sorting was done under Olympus (SZ61) and Euromex (SB1402) stereomicroscopes at 10–40 ×

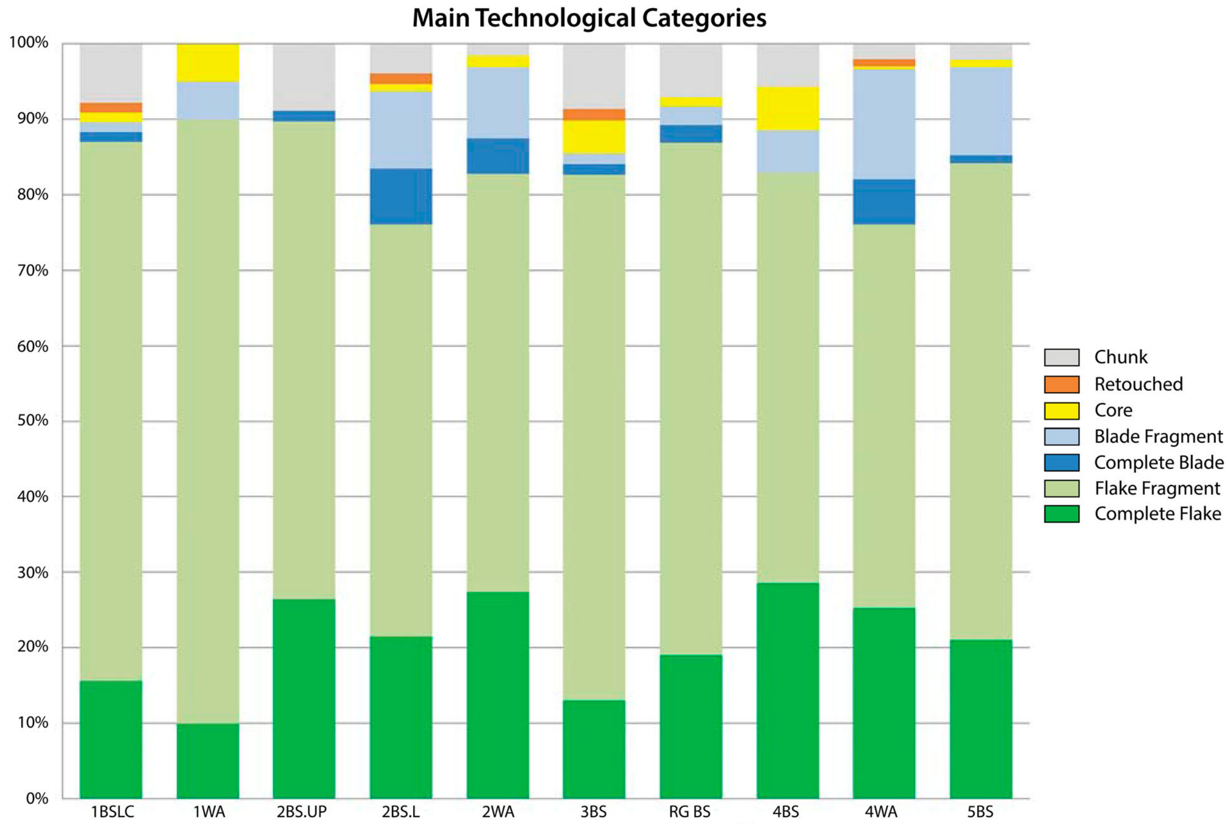

Figure 6. Border Cave frequencies of the main lithic technological categories by member.

magnification. Retrieved botanical remains were packaged in small plastic zip-lock bags inside plastic bottles or boxes. All sorted deposit, including the fine material that passed through the 0.25 mm sieve, has been retained.

Grass is the main component of the bedding material, but sedges and dicotyledonous leaf fragments are also present. The internodes (the stems between nodes) of grass culms are generally round and hollow in section, whereas sedge stems are solid and sometimes triangular (Dorrat-Haaksma and Linder 2012: 38–39). Thus, grasses and sedges should be easily identified, but a complicating issue at Border Cave is that the grass internodes are sometimes solid rather than hollow, notwithstanding the general rule. Internodes are solid in many panicoid and chloridoid grasses (Gibbs Russell et al. 1990: 5) and our preliminary study suggests that broad-leafed panicoid grasses are indeed represented. A few grass and sedge seeds were found, as well as grass and dicotyledonous leaf fragments, twigs, bark, and charcoal. The sedge seeds represented include *Cyperus* sp. and *Mariscus* sp. Dicotyledonous leaf fragments preserve better when desiccated than when burned and the identified ones include *Chionanthus foveolatus* and members of the Sapotaceae family, for example, *Sideroxylon inerme.* The dicotyledonous leaves may have become accidentally incorporated into the monocotyledonous leaf and culm bedding. Anderson (1978) also recovered *Chionanthus foveolatus* leaves from Beaumont's excavation.

As at Sibudu (Wadley et al. 2011), the Border Cave bedding incorporates bone and stone modified by humans, and also some fragments of ochre. This suggests that the bedding patches were working as well as resting areas. Unlike at Sibudu, the Border Cave preservation is so good that pieces of wood and bark are incorporated in the unburnt bedding.

RHIZOMES AND SEEDS

Careful sieving and sorting of organic remains has yielded numerous small, charred rhizomes, particularly in Member 4 WA (MSA 1/Pietersburg). Contrary to other botanical remains such as seeds that may have been introduced in the site by non-human agents like birds or rodents, the presence of the rhizomes is a clear indication that the people using the cave by 168–115 kya systematically collected, processed, and likely consumed these plants on-site. Seeds are from a wide variety of mostly woody taxa (TABLE 3). Some are charred, but many are merely desiccated, even in members as old as 3 BS (basal post-Howiesons Poort). The seeds represent trees and shrubs that are typical of a bushveld habitat. Little more can be said until the seed assemblage has been enlarged.

CHARCOAL

Several hundred charcoal fragments from Members 4 WA and 5 BS (MSA 1/Pietersburg) were subjected to a standard anthracology study. The charcoal was studied with an Olympus SZX16, Munster, Germany and Olympus BX51 at magnifications of 100×, 200×, and 500×. The anatomical features were recorded and digitally photographed using an Olympus DP32 camera and Stream Essentials image analysis software with extended focal image capability. Anatomical features of scanned electron microscope images of fresh woods from a variety of databases were used for comparative identification. The preliminary identifications are listed in Table 4. Most of the taxa represented grow in the Lebombo today. For example, the Border Cave list of woody taxa has many in common with modern taxa from east-facing Gwalaweni Forest on the top of the Lebombo Mountain range between Jozini and Ngwavuma: *Celtis africana*, *Diospyros lycioides, D. whyteana, Ptaeroxylon obliquum, Sclerocarya*

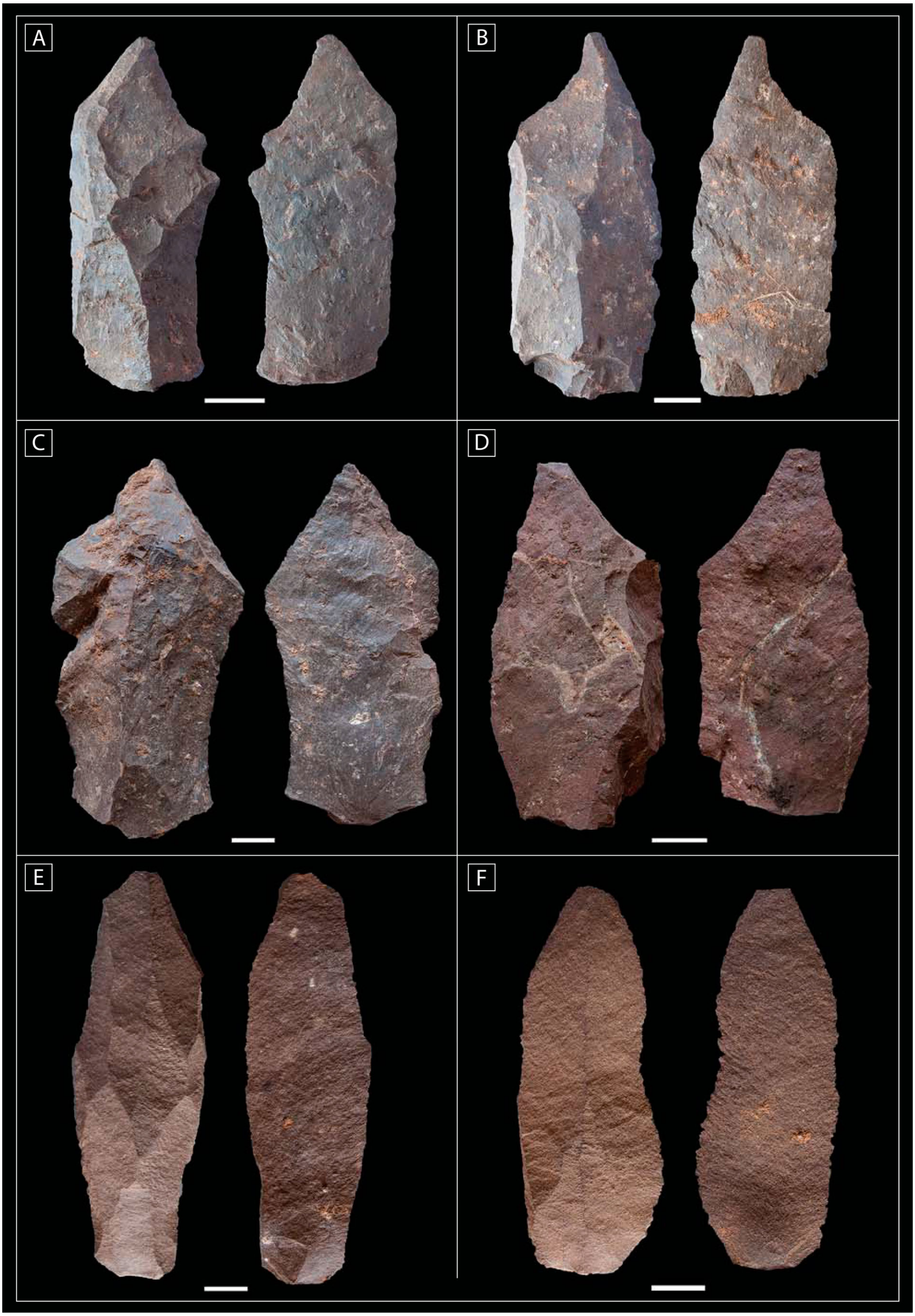

Figure 7. A–F) Border Cave, Member 2 BS Lower, *Levallois* elongated blanks. The scale bars are 10 mm.

birrea, Teclea gerrardii, Tricalysia lanceolata, Turraea floribunda, and *Ziziphus mucronata*. Anderson's (1978) modern survey of the area adds: *Croton gratissimus, Erythroxylum* sp., *Ochna serrulata, Olea europaea* subsp. *africana, Rapanea melanophloeos,* and *Spirostachys africana*. Additional taxa with wide distribution in Maputoland and occurring in both the Elephant Reserve and Licuati Forest Reserve are: *Afzelia quanzensis, Brachylaena discolor,* and *Canthium spinosum* (Sabonet 2002). Other taxa marked present in the area today are recorded in Boon (2010) or our own

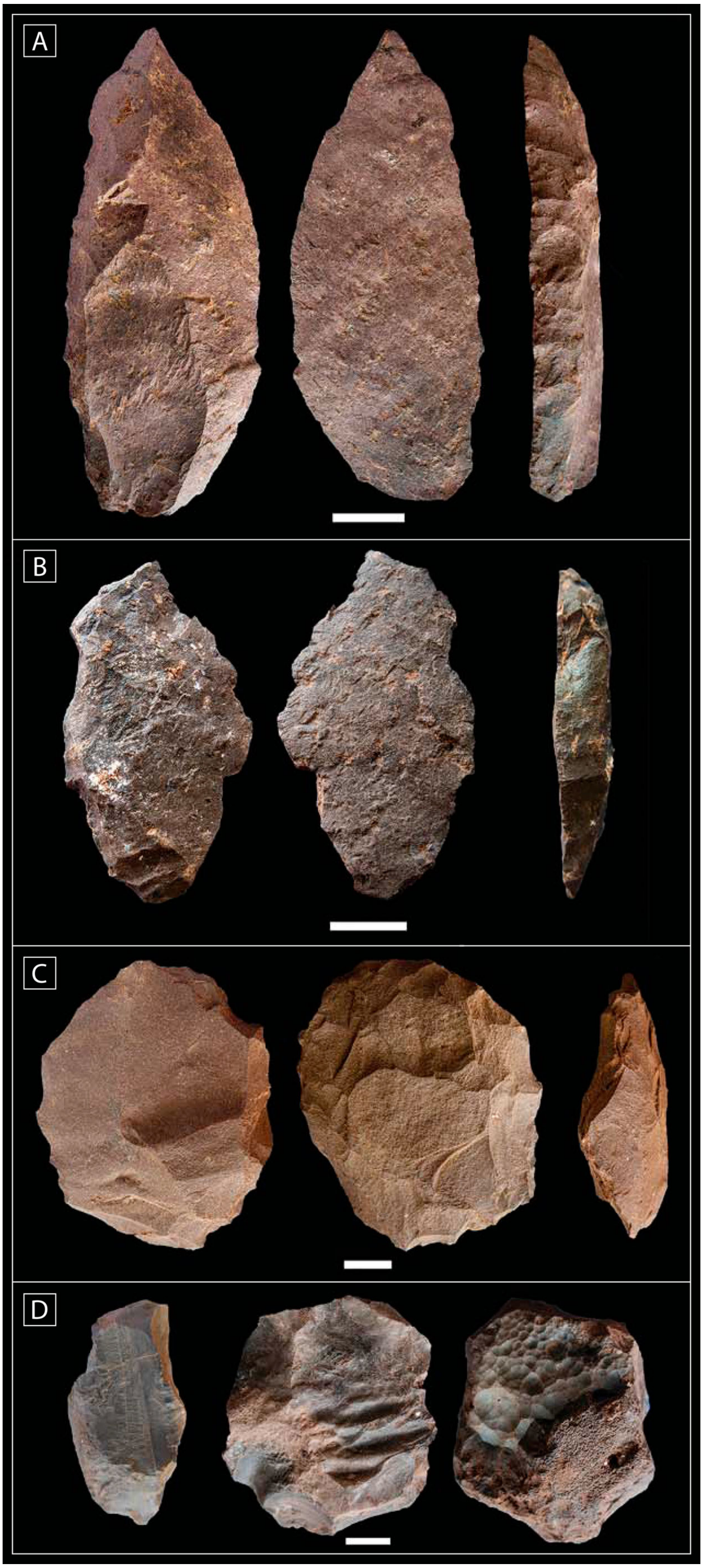

Figure 8. Border Cave, Member 3 BS, A–B) Backed pieces; C–D) *Levallois* cores. The scale bars are 10 mm.

preliminary survey. What is important about the list of charred woody taxa from Members 5 BS and 4 WA is that it suggests a vegetation regime similar to that of today. It does not support Avery's interpretation of miombo woodland, even though it includes some taxa that do not occur in the immediate vicinity of the site today, for example, *Protea* sp. and *Erica* sp., although *Protea gaguadi* has been identified in the area grid 2731BB.

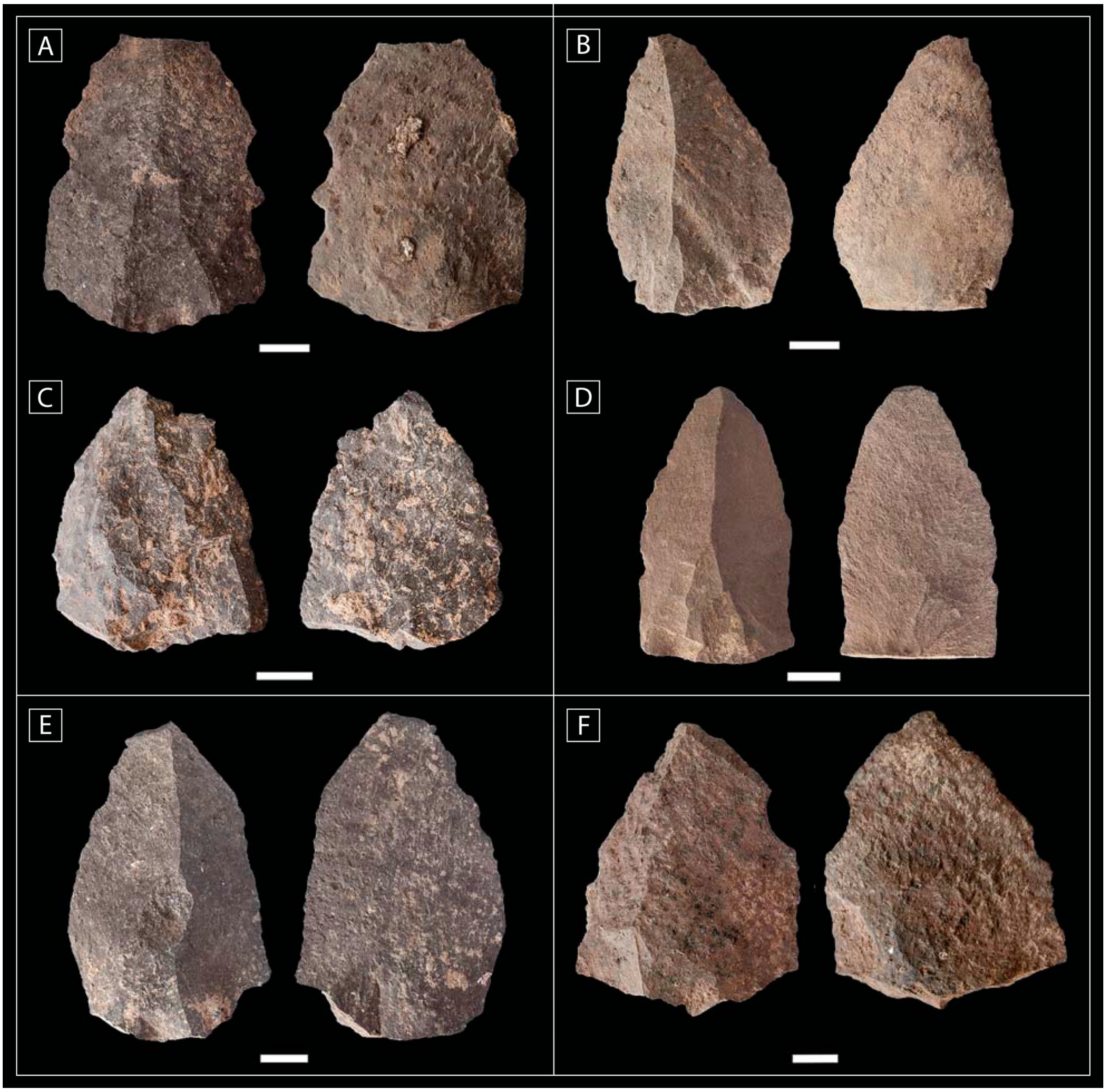

Figure 9. Border Cave, Member 5 BS, *Levallois* points. The scale bars are 10 mm.

Discussion

As explained at the beginning of the paper, Border Cave's archaeological potential was recognized early in the 20th century and, as a result, the site was repeatedly excavated with a focus often on retrieving hominin remains. Cooke and colleagues (1945) excavated the remains of an infant associated with a *Conus* shell and a Howiesons Poort lithic industry. The contextual integrity of this burial has recently been ratified (d'Errico and Backwell 2016). Conversely, the contexts of other hominin remains from the site seem less secure and have been the subject of several critiques (Klein 1983; Parkington 1990; Grine 2016). Among the critiques is the point that Middle Stone Age faunal remains are poorly preserved at the site, whereas the hominin remains are in better condition, suggesting that they are younger than the fauna. We think that our new geoarchaeological techniques will be able to differentiate preservation conditions at the site.

We aim to obtain fine resolution with a minimum of excavation, but sampling the entire cultural sequence. We are reconstructing site formation processes and excavating at a centimeter-scale to recover maximum stratigraphic information from the sequence that Grün and colleagues (2003) have dated by ESR to about a quarter of a million years at its base. We are using a variety of techniques for interpreting the strata, from micromorphology to FT-IR and XRF. Organic preservation and diagenesis is uneven across Border Cave's floor. Much of the site is dry and organic remains are often exceptionally well-preserved. However, we have identified a few small water channels cutting through the strata and where this happened, combustion features and layers of grass bedding were, at places, truncated and replaced with coarse brown sand or gravel and displaced or reworked lithics and bone. On-site use of a portable FT-IR instrument has already demonstrated the usefulness of the technique for characterizing authigenic mineralisation. We are able to show that different mineralization can take place within the same member, for example, calcite is predominant in the white ash of Member 4 WA (MSA 1/Pietersburg) whereas the brown sediment infill of a pit into this same member lacks calcite and is rich in gypsum.

Our new work has begun to flesh out the palaeoenvironmental record currently available for the site. Faunal remains were found in all of the members sampled, and they will be studied and described following the 2018 excavation season.

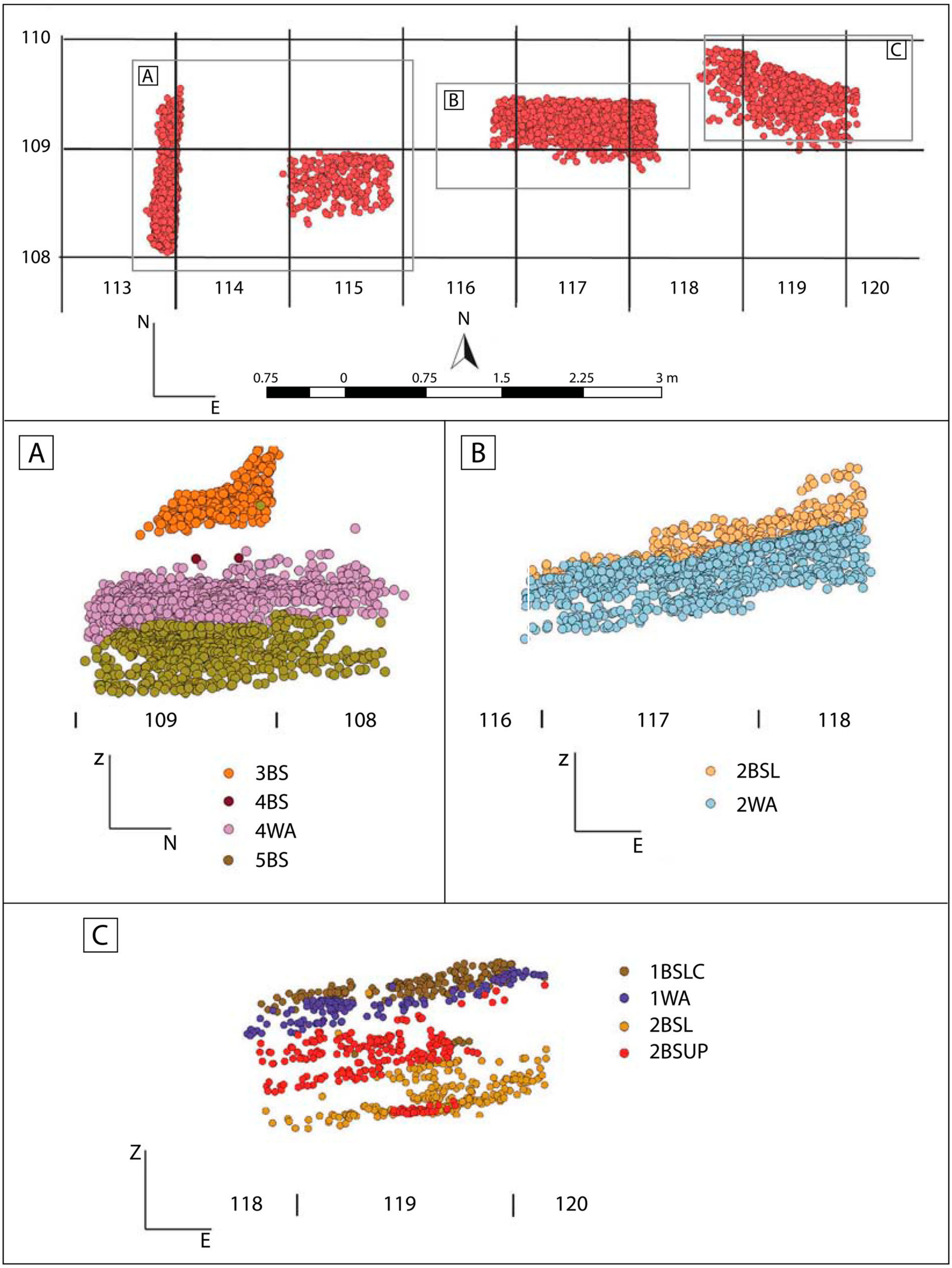

Figure 10. Border Cave 2D plotting of lithics in the four main excavation areas. A) Horizontal plots of lithics from all members in each of the squares excavated: A = Squares N108, E113, N109 E113, N108 E115; B = N109 E116, N109 E117, N109 E118; C = N109 E118, N109 E119. B) Vertical plots of lithics by member in the A, B and C areas shown above. A from top down: Members 3 BS, 4 BS, 4 WA, 5 BS; B from top down: Members 2 BS Lower, 2 WA; C from top down: Member 1 BS Lower, 1 WA, 2 BS Upper, 2 BS Lower.

The preliminary seed and charcoal analyses suggest that vegetation around the site was not dissimilar from that today, at least in the pre-100 kya layers. Nonetheless, taxa identified through charcoal analysis include some that are not presently near the site, for example, *Erica* and *Protea* spp. *Erica*, a resinous shrub favored historically as tinder, grows either near streams or on cool hillsides where *Protea* also thrive. Several bushveld species, such as *Elaeodendron*, are also represented in the seed collection from Member 4 WA (MSA 1/Pietersburg), so Border Cave may have been surrounded by a mosaic of vegetation communities in the same way that Sibudu (about 300 km distant, also in KwaZulu-Natal) was in the

Figure 11. Border Cave grass culm and leaf bedding sample in gypsum plaster jacket. The block is named Ceta and is from square N109 E120, Member 2 BS Upper. The scale bar is 10 mm.

past (Allott 2006). Avery (1992) interpreted micromammalian distributions through time as evidence that miombo woodland or miombo savanna woodland occurred in the Lebombo Mountains during the basal occupations of Border Cave. However, the woody species list of anthropogenically accumulated firewood made during charcoal analysis of pieces from Members 5 BS and 4 WA (MSA 1/Pietersburg) does not support Avery's interpretation.

We present two new radiocarbon ages that fit well with the existing radiocarbon chronology for the younger members of the site. Grass bedding from Member 2 BS Upper (post-Howiesons Poort) yielded a date of 43,300 ± 2700 B.P. (unfortunately this is outside the calibration curve). Grass bedding from Member 1 BS Lower C (ELSA) produced a date of 36,700 ± 900 B.P. (42,533–39,362 CAL B.P.). Both fresh and burned grass bedding layers appear in older Middle Stone Age members, even in the Howiesons Poort Member 3 BS that yielded an age of 72 kya at its base. However, bedding is burned in patches rather than across its full extent, suggesting that grass on the edges of combustion features may accidentally have caught fire. Thus Border Cave bedding does not seem to have been subjected to the same maintenance strategies evident in Sibudu where bedding was

Table 4. Border Cave woody taxa identified from charcoal fragments in Members 4 WA and 5 BS. x = present; - = absent. Locally present: SVI 15 = Northern Lebombo Bushveld; SVI 16 = Southern Lebombo Bushveld; SVI 17 = Lebombo Summit Sourveld; SVI 18 = Tembe Sandy Bushveld (Mucina and Rutherford 2006); other taxa present are recorded in Boon (2010), the SJL/CS/LW survey and South African National Biodiversity Institute (2016).

Name	Member 4 WA	Member 5 BS	Locally present today?
Acacia sp.	x	x	yes
cf. *Afzelia quanzensis*	x	-	yes
Brachylaena cf. *discolor*	x	-	yes
Brachylaena cf. *rotundata*	x	x	no
Canthium cf. *spinosum*	x	-	yes
Canthium cf. *suberosum*	-	x	yes
Canthium sp.	x	x	yes
Celtis cf. *africana*	x	-	yes
Combretum cf. *erythrophyllum*	x	-	yes
Commiphora sp.	x	-	yes
Croton cf. *gratissimus*	x	-	yes
Cryptocarya spp.	-	x	yes
Curtisia dentata	x	x	no
Diospyros cf. *lycioides*	x	x	yes
Diospyros cf. *natalensis*	x	-	yes
Diospyros cf. *villosa*	-	x	yes
Diospyros cf. *whyteana*	-	x	yes
Diospyros sp.	x	x	yes
Erica sp.	-	x	no
Erythroxylum sp.	-	x	yes
Gardenia cf. *volkensii*	x	-	yes
Kirkia cf. *acuminata*	-	x	yes
Mystroxylon aethiopicum	x	x	yes
Ochna cf. *serrulata*	x	-	yes
Olea cf. *africana*	x	x	yes
Ozoroa cf. *paniculosa*	x	-	yes
Protea sp.	-	x	no
Protorhus longifolia	x	-	yes
Ptaeroxylon obliquum	x	-	yes
Rapanea melanophloeos	-	x	yes
Sclerocarya birrea	-	x	yes
Spirostachys africana	x	-	yes
Teclea cf. *gerrardii*	-	x	yes
Tricalysia cf. *lanceolata*	x	-	yes
Turraea cf. *floribunda*	x	-	yes
Vitex cf. *rehmannii*	-	x	yes
Ziziphus cf. *mucronata*	x	x	yes
Identified	186	284	
Studied	203	314	

consistently burned and rebuilt so that deep strata of burnt bedding accumulated (Goldberg et al. 2009; Wadley et al. 2011). The apparent lack of maintenance strategies at Border

Table 3. Preliminary list of identified seeds from 2015–2017 excavations at Border Cave. x = present; xxx = abundant.

Scientific name	1 BS	1 WA	2 BS	2 WA	3 BS	3 WA	1 RGBS	4 BS	4 WA	5 BS
Apodytes dimidiata				**x**						
Asparagus sp.									**x**	
Berchemia zehyeri				**x**						
Celtis africana				**x**						
Coddia rudis				**x**						
Commiphora harveyii				**x**						
Commiphora woodii			**x**							
Commiphora sp.			**x**							
Cyperus prolifer					**x**					
Diospyros sp.										**x**
Diospyros dichrophylla				**x**						
Elaeodendron transvaalense									**x**	
Euclea sp.				**x**					**x**	
Grewia occidentalis			**x**							
Grewia sp.			**x**							
Mariscus sp.			**x**							
Olea sp.	**x**	**x**		**x**					**x**	
Poaceae spp.				**x**					**x**	
Sclerocarya birrea				**x**						**x**
Sideroxylon inerme	**x**		**xxx**						**xxx**	
cf. *Vepris*				**x**						
Vitex sp.			**x**							
Ziziphus mucronata									**x**	

Cave implies that the site may have been abandoned for long periods, rendering treatment of the bedding unnecessary. This conclusion is tentatively supported by the preliminary study of the stratigraphy.

The lithic sequence at Border Cave is of interest for several reasons, not least because it is of considerable antiquity, beginning about a quarter of a million years ago. In addition, the site is said to house a Pietersburg Industry and one of the earliest examples of the Later Stone Age. At present, our Border Cave lithic sample size is largest for the assemblages thought to be Pietersburg so we are in a better position to study this Industry in detail than any of the others. Beaumont and colleagues (1978) commented that Member 4 WA (Pietersburg) lithics were four times as dense as post-Howiesons Poort lithics from Member 2 BS and certainly our excavations confirm the high density of Pietersburg lithics.

The name Pietersburg Industry was used by E. G. Paterson in the late 1920s for a lithic assemblage near Pietersburg (now Polokwane, in Limpopo, a Province of South Africa) (Sampson 1974). Later, Goodwin and van Riet Lowe (1929) adopted the name for various surface scatters, but the industry remained poorly defined. When Cooke and colleagues (1945) excavated Border Cave they assigned lithics from the oldest Members (which they called BACO [6 BS, 5 WA, 5 BS, 4 WA]) to 1 GBS (renamed 4 BS by Beaumont) to the Pietersburg Industry. They identified *Levallois* technique, with many flakes showing convergent longitudinal flaking and, at the base of the excavation, they found a fragment of a bifacial point (they said that it resembled Still Bay from the Cape, but in the first half of the 20th century this term was often indiscriminately used for any type of bifacial point). Border Cave's Pietersburg flakes were said to be relatively large, and broad in proportion to their length, and typical specimens were 8 to 9 cm long and 4 to 5 cm wide, with striking platforms mostly plain or with rudimentary preparation. Subsequently, Beaumont (1978) provided detailed typometric and typological descriptions of the site's entire sequence, together with raw material identifications. A key Pietersburg site for comparison with Border Cave is the large, deep, brecciated Cave of Hearths in the Makapan Valley, Limpopo. The Cave of Hearths breccia was first worked in 1937 by van Riet Lowe and Malan, then in the 1940s by Kitching and Gardner, and later by Mason who removed consolidated breccia with dynamite (Mason 1962, 1988; Sinclair 2009). Cave of Hearths was said to have a long Pietersburg sequence: Lower (Bed 4), Middle (Bed 5), and Upper (Beds 6–9) Pietersburg (Mason 1962, 1988). Although the Pietersburg is supposedly characterized by large, elongated products, including long, retouched points manufactured on blades (Tobias 1949; Mason 1962; Sampson 1974), Sinclair (2009) points out that there is considerable variability through time in the Cave of Hearths Pietersburg. The deepest MSA beds (e.g., Bed 4) have abundant use of prepared core technology, but retouched pieces other than denticulates and side scrapers are rare until the middle of Bed 6 when unifacial points increase considerably (Sinclair 2009: 113). A similar sequence may be represented at Border Cave, but what is different is that Beaumont and colleagues (1978) illustrated bifacial (and unifacial) points in the Pietersburg members of Border Cave, whereas only three bifacial points were found in the whole Cave of Hearths MSA sequence (Sinclair 2009: 113). Bifacial points were reported from Border Cave Members 6 BS to 4 BS with ESR ages between 227 and 77 kya (Beaumont et al. 1978; Grün and Beaumont 2001; Grün et al. 2003). Bifacial points have been documented in other MSA assemblages thought to belong to the Pietersburg Industry, for example, Mwulu's Cave (Tobias 1949) and Bushman Rock Shelter (Plug 1981; Porraz et al. 2015), both of which have undated MSA sequences. Wonderwerk Cave (Northern Cape) and Border Cave seem to have contemporary Pietersburg sequences. At Wonderwerk, where dates for the Pietersburg are between about 220 and 70 kya, there are prepared cores, *Levallois* flakes, and unifacial and bifacial points (Beaumont and Vogel 2006). Even older open-site MSA assemblages at Kathu Pan, Northern Cape, and Florisbad, Free State, may be Pietersburg Industries, but this is uncertain. MSA lithics were found at Kathu Pan, in Stratum 3 sediments that date 291 ± 45 kya (Wilkins and Chazan 2012), and a small collection of MSA stone artifacts that cannot be attributed to a particular industry is associated with an age of ca. 259 kya at Florisbad (Kuman et al. 1999).

Thus, the Pietersburg Industry remains poorly understood and it clearly needs to be revised after detailed technological studies and dating programs. Early on, Goodwin and van Riet Lowe (1929), Mason (1962), and Sampson (1974) observed that the Pietersburg only occurs inland in South Africa and that it may be absent north of the Limpopo River. Notwithstanding extensive archaeological work in South Africa in the past 50 years, this observation remains valid. The new excavations at Border Cave offer an ideal opportunity for a Pietersburg lithic project, but also for others, such as a technological examination of the post-Howiesons Poort assemblages. The post-Howiesons Poort 58 ka old assemblages from Sibudu have now been described in detail (Conard et al. 2012; Conard and Will 2015; de la Peña and Wadley 2017). The Border Cave post-Howiesons Poort assemblages have a similar age and a comparison between the industries of the two sites should be profitable. Such a study is particularly important because post-Howiesons Poort assemblages are poorly represented in the southern part of South Africa where most Stone Age research has been conducted. Other lithic projects will, nonetheless, be equally promising, such as a study of this northerly, inland expression of the Howiesons Poort and a re-examination of the ELSA which is thought to be the earliest expression of the Later Stone Age in southern Africa (d'Errico et al. 2012; Villa et al. 2012). A number of cultural innovations such as ostrich eggshell beads are linked to the ELSA at Border Cave, and organic preservation is exceptional. Villa and colleagues (Villa et al. 2012) supported Beaumont's (1978) conclusion that the ELSA assemblage largely comprises bipolar blanks and cores.

Because we are working slowly and with fine resolution, our new excavations have targeted small volumes of sediment from each member. Consequently, the samples of lithics are still limited and this is not ideal because the results of the technological analyses are different when (for the sake of creating a reasonable sample size) industries are combined by member attribution, rather than separated by layer. Our preliminary study at Border Cave demonstrates that there are technological differences implied by the lithic assemblages of layers distinguished within the same member and these are masked by combining data from layers. Member 2 BS (post-Howiesons Poort) is an example of the problem here because the Lower and Upper layers have different lithic profiles. Such diversity might correspond to functional variability within the same cultural tradition, or to other behavioral or taphonomic causes. However, it can also mean that, from a technological perspective, the original grouping of layers into larger members was incorrect. As has been shown in recent lithic technology analyses in Sibudu Cave (e.g., Conard and Will 2015; de la Peña and Wadley 2017), the in-depth analysis of finely-separated layers can provide high resolution interpretations of cultural behavior (such as spatial organization, mobility patterns and change through time). Studying the archaeological material according to finely resolved stratigraphy could be one major contribution of our new excavations because of the novel behavioral interpretations that this might bring. Moreover, since some areas in the cave have outstanding organic preservation it would be worth trying, in the future, to correlate fine resolution lithic analyses with analyses of, for example, botanical remains. Such studies can bring a new perspective to the Middle Stone Age.

Border Cave is an exceptional site in the southern African context. It is among only a few excavated Middle Stone Age sites in southern Africa with occupation probably extending back to a quarter of a million years ago. Furthermore, it is one of only a few Middle Stone Age sites with human remains, exceptionally good organic preservation, and a long and well-developed cultural sequence. This inland site, more than 80 km from the Indian Ocean, contains a rare archive that is particularly valuable because most archaeological work in southern Africa is focused on sites along the southern Cape coast of South Africa.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

Notes on Contributors

Lucinda R. Backwell (Ph.D. 2004, University of the Witwatersrand and University of Bordeaux) is affiliated to the Instituto Superior de Estudios Sociales (ISES-CONICET), Tucumán, Argentina. Her research interest is the Stone Age of South Africa, experimental taphonomy and the study of bone tools.

Francesco d'Errico (Ph.D. 1989 and H.D.R 2003, Muséum National d'Histoire Naturelle, Paris; University of Bordeaux) is a Research Director at the Centre National de la Recherche Scientifique. His research focuses on the origin of symbolic behavior and bone technology in Europe, Africa, and Asia, Neanderthal extinction, and the impact of climate change on cultural evolution.

William E. Banks (Ph.D. 2004, University of Kansas) is a permanent Researcher at the Centre National de la Recherche Scientifique. His research interests include the Middle Stone Age, the late Middle Palaeolithic and the Upper Palaeolithic of Europe, culture–environment relationships, and the application of ecological niche modeling methods and theory to the archaeological record.

Paloma de la Peña (Ph.D. 2011, Universidad Complutense de Madrid) is a postdoctoral research fellow at the Evolutionary Studies Institute and an Honorary Research Fellow in the School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, South Africa. Her main research interests lie in understanding cultural evolution within *Homo sapiens* societies. She conducts technological studies of lithics.

Christine Sievers (Ph.D. 2013, University of the Witwatersrand) is a senior lecturer in the Archaeology Department, University of the Witwatersrand, Johannesburg, South Africa. She specializes in archaeobotany and experimental archaeology and focuses on macrobotanical remains from the Middle Stone Age, particularly fruits, seeds, geophytes and bedding materials such as sedges and grasses.

Dominic Stratford (Ph.D. 2011, University of the Witwatersrand) is a senior lecturer of Geoarchaeology in the Archaeology Department, University of the Witwatersrand, Johannesburg, South Africa and also Research Director at the Sterkfontein Caves, one of the premier hominin sites in South Africa. His research interests are geoarchaeology, karst geomorphology, archaeological excavation methods, vertebrate taphonomy, sedimentology, sediment micromorphology, palaeoanthropology and stratigraphy.

Sandra J. Lennox (Ph.D. 2016, University of the Witwatersrand) is a postdoctoral research fellow at the Evolutionary Studies Institute, University of the Witwatersrand, South Africa. She specializes in anthracology and has identified woody species from charcoal at Sibudu and Border Cave.

Marine Wojcieszak (Ph.D. 2014, Université Pierre et Marie Curie (UPMC), Paris VI) is a postdoctoral research fellow in the Evolutionary Studies Institute, University of the Witwatersrand. She obtained her Ph.D. in Physical Chemistry and Analytical Chemistry. Her current research involves the non-destructive analysis of Middle Stone Age (MSA) artifacts and their context for understanding the behavior and cognition of MSA people. Specifically, she is using a multi-analytical approach (including Raman spectroscopy, Fourier transform infrared spectroscopy, X-ray diffraction, Scanning Electron Microscopy and X-ray fluorescence spectroscopy) to characterize, for example, ochre pieces, stone tools and their residues, sediments and resins excavated from Sibudu, Rose Cottage, and Border Caves.

Emese M. Bordy (Ph.D. 2001, Rhodes University) is a lecturer at the University of Cape Town. Her main research interest lies within the Palaeozoic and Mesozoic deposits of Africa with a strong focus on the quantification of the climatic and tectonic signatures in sedimentary and biogeographic processes. She is passionate not only for applying sedimentology, stratigraphy, continental ichnology, and palaeontology to palaeoenvironmental reconstructions, but also for integrating multidisciplinary observations at various scales to obtain robust palaeoecological snapshots of the African geological past.

Justin Bradfield (D.Litt et Phil. 2014, University of Johannesburg) is a postdoctoral research fellow in the Evolutionary Studies Institute, University of the Witwatersrand, South Africa. He specializes in the study of bone tools and micro-tomography and has an interest in poisons used in the past.

Lyn Wadley (Ph.D. 1986, University of the Witwatersrand) is an Honorary Professor of Archaeology in the Evolutionary Studies Institute, University of the Witwatersrand, South Africa. Her research interests include the Middle Stone Age, experimental archaeology and cognitive archaeology. She has excavated at many South African sites, for example, Sibudu and Rose Cottage Caves.

ORCID

Lucinda R. Backwell http://orcid.org/0000-0001-5816-3353
Francesco d'Errico http://orcid.org/0000-0002-2422-3079
William E. Banks http://orcid.org/0000-0003-1835-6315
Paloma de la Peña http://orcid.org/0000-0001-9731-7001
Christine Sievers http://orcid.org/0000-0001-5704-6913
Dominic Stratford http://orcid.org/0000-0001-9790-8848
Sandra J. Lennox http://orcid.org/0000-0003-0078-3685
Marine Wojcieszak http://orcid.org/0000-0001-9508-4697
Emese M. Bordy http://orcid.org/0000-0003-4699-0823
Justin Bradfield http://orcid.org/0000-0002-6139-6227
Lyn Wadley http://orcid.org/0000-0003-0053-0813

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