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THE HANNIBAL ENIGMA OF 218 BC: A FORENSIC EXERCISE OF IMPORTANCE TO HISTORICAL ARCHAEOLOGY

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ABSTRACT

Following a long and protracted survey of all approaches to targeted approach routes, cols of passage and exfiltration pathways projected to have been followed by Hannibal and his generals when they crossed into Italy in 218 BC, the physical evidence points to the Col de la Traversette, first identified by Sir Gavin de Beer in the 1960's. The first attempts to identify the route out of a dozen possible transits, focused not only on historical interpretations using the evolution of place names in Polybius and Livy by Sir Gavin de Beer, but on physical evidence possibly resident in hearths, alluvial terraces and rock rubble masses along the various approach routes. The rockfall blocking Hannibal's Army, looming large in Livy's rendition of the invasion, and less so in Polybius's Histories, still presented a blockade to passage of horses and elephants, an impediment to a fast exit from the mountain col to the lowlands of the Po river. Aside from the two-tier rockfall described by Polybius, and the nearby regrouping area on the lee side of the Alps, it eventually occurred to me to investigate the mires on the French and Italian sides of the Col de la Traversette. The primary argument following ten years of investigating every approach route from the Col Agnel in the south to the Col Mt. Cenis in the north, was that if the only blocking rockfall was present below the Traversette col, then mires on either side in France and Italy might, with their soft to coarse sediment covers, contain a record of Hannibal's passage. Beyond their key positions as water sources and foraging areas, the French mire and coalescing alluvial fan sediment in the upper Po, might carry evidence as to the ecologic disturbance that could be radiocarbon dated to the Hannibal time line of 2168 cal yr BP or 218 BC. It is this long quest to unlock the Hannibalic invasion route that opened up key areas for historical archaeological exploration. This forensic cross/discipline exercise might serve to highlight a valuable method useful in solving other elusive ancient historical archaeological problems.

Keywords: Hannibalic invasion route; forensic analysis of mire sediment

1. INTRODUCTION

The question of the route followed by Hannibal and his army in 218 BC, 2168 cal yr BP (BP=before present, 1950 AD) has rankled and irked historians and classicists for millennia (Freshfield, 1886, 1899; Dodge, 1891; de Montholon, 1905; Wilkinson, 1911; Walbank, 1956, 1990; Brown, 1963; de Beer, 1956, 1967, 1969, 1974; Seibert, 1993) amongst others. No less than seven books were written about the invasion in Hannibal's time (Proctor, 1971), the last known of which (by Silenus, Hannibal's historiographer) was destroyed by the great fire that consumed the library at Alexandria in 300 AD. Since then a number of workers have posited possible routes (Fig. 1), basically dependent upon previous sources including the texts of Livy (trans. de Sélincourt, 1965) and Polybius (trans. Paton, 1922; Scott-Kilvert, 1979), but few have visited the sites in question making their target cols all based on second-hand information. While some have tried to correlate descriptions in ancient texts to the actual landscape and flooding times of rivers (de Beer, 1969), none have coupled the present environment with major topographic features in the ancient texts, let alone searched hearths, likely campgrounds, possible rockfall impediments to the exfiltration of the mountains. It is the purpose of this summary to outline the thinking that went into trying to elicit an environmental matrix from the ancient texts, one that could be tested against the present landscape, a forensic exercise if you will (Mahaney, 2004, 2008a; Mahaney et al., 2008a, b, c).

Assessing the Hannibalic Route one is faced with countless authorities arguing for one of the three principal routes over the other and most key authorities (Proctor, 1971; Lazenby, 1998; Lancel, 1999) opting for the northern route principally because of lower elevation and ease of access. Only de Beer (1967, 1969, 1974), Prevas (1998), and Bagnall (1999) favor the southern route principally because times of flooding, place name matches, and view onto the Po plains closely align with Polybius and Livy. The middle route outlined by Connolly (1981) pitches indecision into Hannibal's thinking that once along the Isère and near Grenoble he would have shifted priority to finding the Col de Genèvre, the most unlikely deviation of travel plans. To enter into this historic mix, a daunting task as it were, required a test of environmental parameters elicited from the ancient texts of Livy and Polybius, forming a matrix of interconnected variables to determine which of the three routes, historic speculation aside, might be closest to the actual route traveled by the Punic Army.

Despite the thinking of some workers that the landscape has changed greatly since the time of Hannibal's invasion, it is clear from environmental summaries published by Sodhi et al. (2006), Mahaney (2008a) and Mahaney et al. (2008a, b, c; 2016, 2018a) that the landscape we see today, despite many slight modifications by stream erosion and avalanche activity over the last two millennia, is the same as that seen by Hannibal and his army when they crossed into Italia in 218 BC. The landscape was set in place during the Late Pleistocene (the last ice age as it were), the final touches taking place during the Bølling and Allerød interstades that marked the first warming time since the retreat of ice, followed by a cosmic airburst of 12.8 ka (12,800 yrs) that fired the surface leaving a carbonized record in the land surface now resident in paleosols (ancient soils) and rock rinds (Mahaney and Keiser, 2013; Mahaney et al., 2013, 2014, 2016, 2017d, 2018b). This airburst event, termed the black mat is also defined as the YDB-Younger Dryas Boundary-that marks the transition into a cold period called the Younger Dryas (YD, 12.8-~11.5 ka), a term resulting from earlier pollen work that identified variable pollen concentrations of the cold loving plant (*Dryas octapetala*) in many alpine regions. The distribution of this plant increased during the Younger Dryas event, a glacial resurgence that resulted from a cold time, similar to a nuclear winter, projected to have been caused by the black mat airburst.

The black mat event is known to have affected North, Middle and South America, Greenland, western Europe, Central Asia, (Wolbach 2018a, 2018b), and is thought to have reached Antarctica (Mahaney et al., 2018c). Its effect on the Western Alps, particularly the area around the Mt. Viso massif was profound, burning the land surface and creating the largest accumulation of soot recorded so far in Western Europe (Allen West, personal communication, 2016; Mahaney, 2019). Portions of bedrock and much exposed glacial sediment were carbonized and melted by temperatures topping 2000 ^{o}C. The event presumably melted all or most glacial vestiges of the ice age, to be shortly replaced by a resurgence of ice forming during the ensuing nuclear winter which produced revived positive glacial mass balances for more than a millennium.

The YD event lasted for ~1.4 kyr, ending by ~11.5 ka when glaciers worldwide went into recession, nearly disappearing in some cases by the Holocene/Pleistocene boundary (~10 ka). By this time the landscape through which Hannibal passed had been set in place, all further change attributed to minor amounts of air-influxed material into soils and paleosols and mass wasted sediment additions to valley side locations (e.g. the younger rockfall sheet identified by Polybius) in local valleys). Losses of sediment accrued in valleys by stream erosion and development of Holocene terraces but for the most part the landscape seen today is what Hannibal and his troops saw when they ventured forth across the Col de la Traversette. The impediments to exfiltration faced by Hannibal are the very same as exist today on both the French and Italian sides of the Western Alps. It is within this matrix of bedrock and deposits that the search for environmental evidence related to the invasion began in 2002. Starting as a means of matching topographical descriptions and relative changes of elevation mentioned in ancient texts, the study soon morphed into a forensic test requiring the use of methods from diverse disciplines to answer questions related to camping places, foraging areas, deposit impediments, river crossings and other environmental targets as it might have affected time motion analysis of the Punic Army.

Polybius provides us with specific day-indicators of the invasion which allow for a total time travel of five months for the march from New Carthage to the Po plains, with four days from the Rhône crossing to the island, ten days from the island to the beginning of the ascent of the mountains, followed by fifteen days to reach the col. The assumption is that the fifteen days are included in the five months but Polybius is not certain about this. We do not know what Polybius meant by 'ascent of the Alps' as this quote may mean ascent of the Dauphiné Alps or ascent following the debacle in the Combe de Queyras (Mahaney and Tricart, 2008). Taking the Rhône crossing to the island to be approximately 40 km, the next leg to the Col de Grîmone a total of 180 km and allowing for negotiations and resupply efforts with local tribes at Orange to take 2-3 days, it is likely this might consume two weeks. If this is correct then the fifteen days to reach the col would include 105 km from the Col de Grîmone to Durance basin, 5 km Durance to Guil catchment, 50 km Guil to Traversette, a total of 160 km and would entail significant time to offset the Durance crossing difficulties, battle in the Combe de Queyras, and reorganization in the upper Guil probably taking six to eight days. The distance from the col to the Po plains is 30 km, the last ten km taken up traveling through a steep gorge.

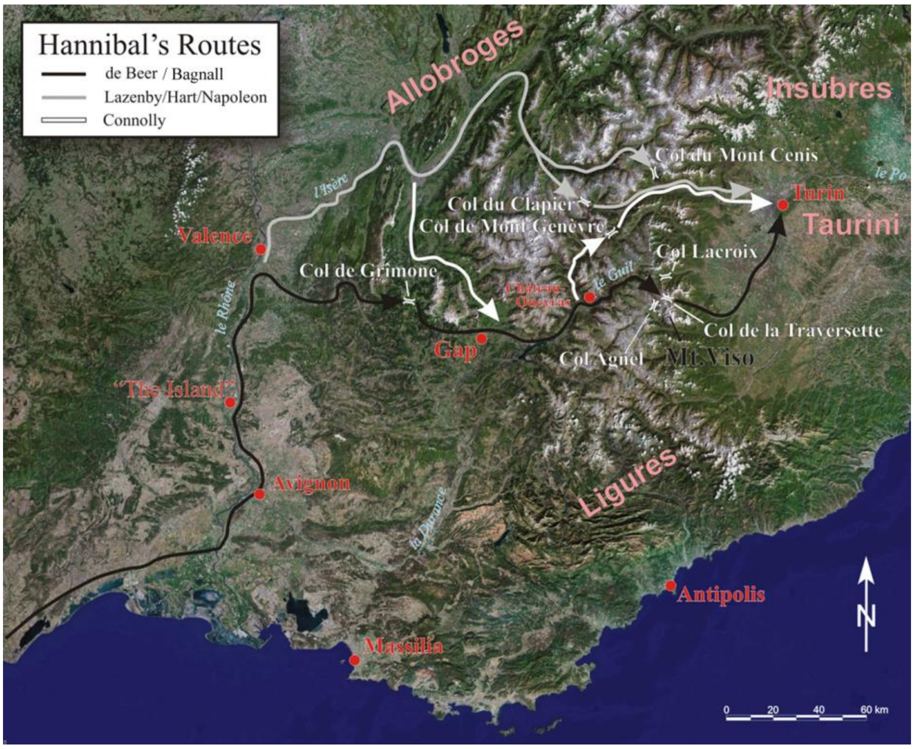

Fig. 1. Invasion routes as proposed by several classicists. Figure reprinted after Mahaney (2008) and Mahaney et al. (2017a).

Of the three routes identified in Fig. 1, both the northern and southern routes are approximately the same distance, only the terrain difference causing a slower rate on the southern leg. The middle route favored by Connolly (Fig. 1) is longer by about 50 km and would have brought the Punic army to within the territory of the Allobroges for a longer period that would have entailed many delays due to engagements relative to the southern route. Putting time distance together for the full route, Polybius gives the distance as 9000 stadia (1597 km). During the first century BC, Strabo calculated 8.5 stadia to the Roman mile which equates to one stadium equal to 177.8 m. The Roman stadium is 0.1778 km, somewhat shorter than an Olympic stade which is 0.184 km or 185 m. Distances were summarized by de Beer (1969) who assumed Strabo's calculations equaled Polybius' distances converted to km's as cited above.

Of all the environmental parameters mentioned in the ancient texts of Polybius and Livy, including: nighttime attack on a col along the approach, snowline elevations, frozen ground (possibly permafrost), long defile below the ascendant col of passage, camping ground near the summit, hearths, view across the Po river plains, rockfall blockade during exfiltration to the Po river, regrouping area on the lee side, the one key element to identifying the route is the large, robust *two-tier rockfall*. All cols of passage have rockfall on the lee side of the Alps but the only pass with a large rubble sheet on the Po river side, one which could have impeded exfiltration, lies below the Col de la Traversette (~3000 m asl). As discussed by Mahaney et al. (2008c, 2010b, 2010c), this is the key element in the route puzzle that has mystified historians and classicists for over two millennia, and the one geomorphic feature as described by Polybius that certifies the southern route identified by Sir Gavin de Beer as the only possible entrance into cis-alpine Gaul transited by the Punic Army in the opening phase of the Second Punic War. Identification of the invasion route hinges on the doublet rockfall (Fig. 2 for location; Fig. 3, View from the East), all other criteria, whether on the land surface or in section below the surface, must occupy a tangential position in the reconstruction on both the French and Italian sides of the Alps. Because most historians writing over centuries about the Punic Wars recounted historical documentation only with little regard to time/motion analysis of the Punic Army, and with scant attention paid to environmental variables recounted here, it is easy to see why belief structures aligned with different groups favored one route over another. This, combined with a lack of ground truthing of routes tied to the ancient literature, led to embedded historical hypotheses lacking any evidence providing an outcome with little chance of finding artifacts that might support a particular route.

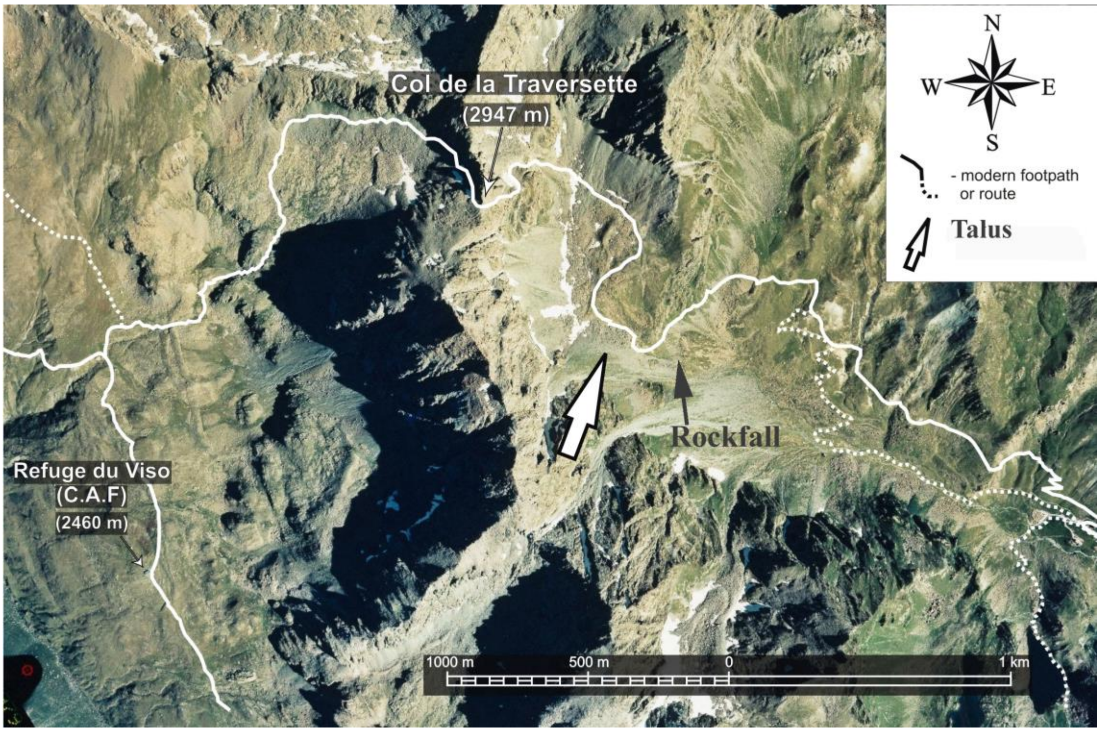

Fig. 2. Traversette rockfall, the main impediment to Hannibal's exfiltration from the Alps. Figure after Mahaney (2008a).

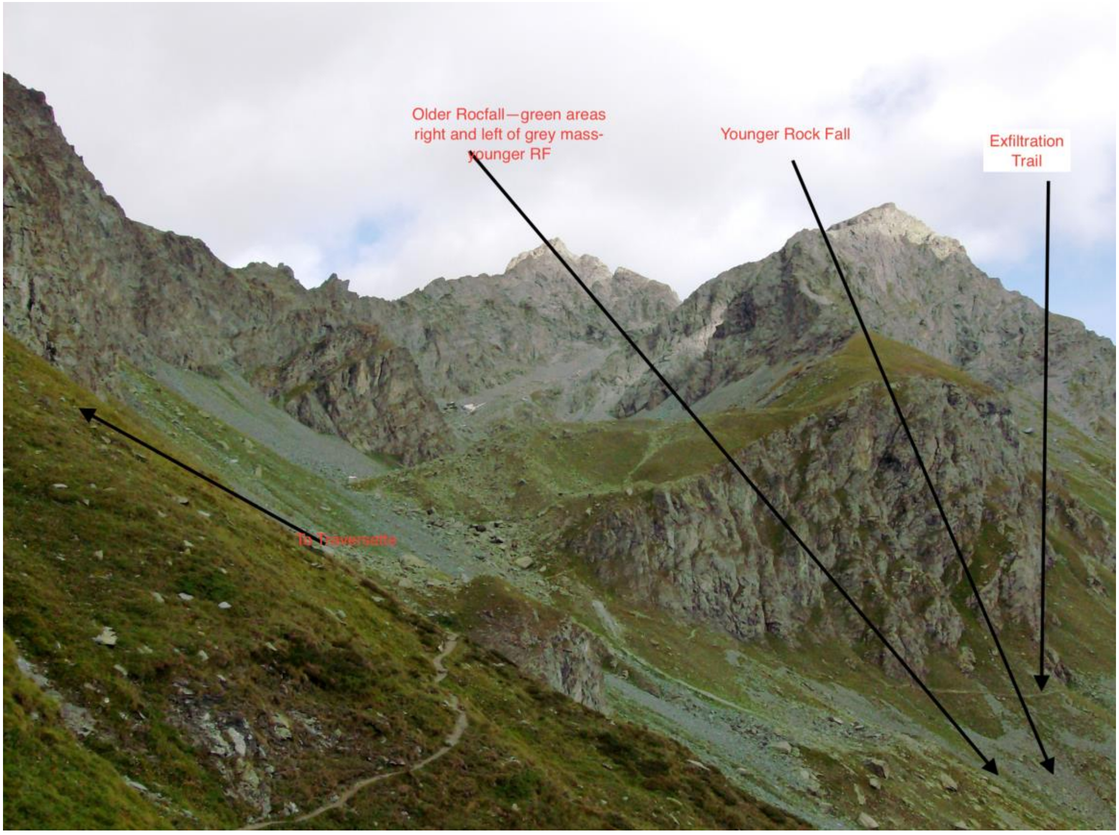

Fig. 3. Position of the rockfall relative to Mt. Granero and the Col de la Traversette. Photo credit to Luca Bergamasco (Creative Commons Attribution 3.0, Unported License. From Mahaney (2020).

Despite other route hypotheses expounded upon by many historians, including mention of routes closer to the Mediterranean coast and others further afield in Switzerland, such as the Great St. Bernard Pass one has to consider Hannibal's prime strategic objective pointed out by Hart (1967)---Linkage with Gallic tribes in cis-alpine Gaul—the Ligurian, Boii, and Insubre tribes with whom Hannibal had established contact prior to the invasion. Travelling too close to the Mediterranean Coast would allow the Romans to maintain contact along the way and travelling north of the Isère River would add to transport time, thus causing delays. Considering that Hannibal had reasonable information from agents sent to contact Gallic tribes in 219, returning to New Carthage (Polybius, III, 34) in spring 218 BC, and as expressed by Polybius it is reasonable to assume he had knowledge of all major passes leading out of trans-alpine Gaul and that his objective col was the Col de Genèvre at ~2000m asl. Because the Gauls were shadowing him following departure of lowland Gallic cavalry sent from Orange as guides (Polybius III, 50), the Allobroges must have assumed Hannibal's intended crossing target, and realizing they could easily attack and defeat him with his cavalry ineffective in the narrow confines of the pass, they closed up on his rearguard (Polybius III, 52). Thus, with the Allobroges behind and ahead at his col target, either Hannibal or his second-in-command, Maharbal, must have deviated into the Guil River and the gorge (Combe de Queyras) just beyond the Durance/Guil confluence (Fig. 1) as a means of bypassing the Allobroges. However as described by Polybius (III, 53), with the flanks unprotected the Allobroges carried out an enfilade attack hurling boulders and other loose debris from the heights onto the soldiers transiting the gorge and with terrifying effect. Aside from the rockfall (Fig. 3) in the lee side of the range, no other approach route carries the gorge obstacle described by Polybius and Livy. In addition to the gorge and rockfall, all other environmental parameters described below line up with arguments presented previously by Sir Gavin de Beer (1956, 1969) and fully support his southern route hypothesis.

2. REGIONAL BACKGROUND

The regional background to the environmental constraints facing Hannibal and his troops is well explained in several works, notably, de Beer (1956, 1969), Proctor (1971), Lancel (1999), Bagnall (1999), Mahaney (2008a), amongst others. Plunging into the environmental evidence that might be used to target key sites requiring historical archaeological reconstruction has been the prime motivation behind work carried out by Mahaney (2004, 2008a), Mahaney et al. (2007b, 2008c, 2010a, b, 2010b, c, 2014) involved searching through possible reconstructions using methods from several disciplines, including geology, geomorphology, topography, astronomy, ecology, philology, palynology, chemistry, and geochemistry. This differs substantially from other earlier attempts to identify the route, some aimed at naming the route through a local municipality simply to satisfy tourist activity (Proctor, 1971). Others centered on topography and the elevation of local cols supported by previous military strategists, Napolèon for example, that Hannibal had to have used a particular route. Conversely some routes were considered just too difficult for Hannibal to have negotiated steep inclines and narrow ledges to move his animals and soldiers into Italia. Many workers seem to forget or overlook that Hannibal had a standing professional army and that his soldiers were not only capable of rapid movement, they were unencumbered by non-combatants and other non-essential personnel, and were used to movement in mountainous terrain.

Moreover, as previously outlined, the idea that the Hannibalic Army moved through a landscape vastly different from today has been disproven by glacial geological (Mahaney, 2008; Mahaney et al., 2016a) and cosmic airburst (Mahaney and Keiser, 2013; Mahaney et al., 2018b) studies that show the landscape seen today is essentially the same as that seen by Hannibal and his troops. The only modifications to the land surface result from minor input of aeolian-influxed sediment to soils and paleosols, minor stream incision, and increase in the thickness of mass wasted deposits emplaced in the form of solifluction deposits, debris flows, and rock and snow avalanches. Col elevations have changed little since Hannibal's time mostly with slight tectonic shifts raising height by a few meters.

3. RESULTS AND DISCUSSION

Initial research stage

Combining expertise as an environmental scientist working in various mountain environments on all continents over several decades, coupled with an interest in classical history, it is not unexpected that Hannibal's invasion over one of the most imposing mountain chains on Earth might pique my interest in focusing on just how and where the invasion was carried out. Hannibal's feat of moving large numbers of troops, support personnel, horses, mules, let alone elephants, across elevations up to 3000 m has few rivals including such figures as Caesar, Belisarius, Charlemagne, Napolèon, even including such modern figures as Rommel in the Alps and the American 10th Mountain Division in the Aleutians. Only Napolèon comes close to the number count of the Hannibalic Army, and he, it seems never ventured close to the 3000 m mark. The question of the route itself has been the driving force of historians and classicists who usually quote each other in constructing 'proofs' of the invasion route, very few ever visiting the approach routes and cols in question. Up to the time of Mahaney (2004, 2008a) no one attempted to target key sites where historical archaeological exploration might reveal artifacts related to the invasion of Hannibal or the later crossing of his brother, Hasdrubal, in 207 BC. Motivation to define the route, some consider to be the great question of antiquity (personal communication, T. Corey Brennan, 2004), seems to lie in the route designation itself, not to target key sites worth historical archaeological exploration. This seems a strange quest to me as given the fact that the Hannibalic Army emerged onto the Po River plains, the route itself of little consequence except that a route designate itself narrows the area of possible archaeological exploration. Moreover, documentation of key sites to explore might lead to the recovery of important information to elucidate the military culture of ancient Carthage. Hence, the environmental targets soon came to carry prime importance in this forensic exercise.

Environmental Matrix

Reading Polybius and Livy, one comes away with a certain briefness attained by both historians describing the invasion, most probably because few could write and most place names were spoken only, maps way off in the future. That Hannibal probably had sketch maps made by his agents who crossed the Alps into northern Italia, it is a given that he probably knew in advance the positions of most major routes, including those that sourced from the Durance and Isère valleys. We may only suppose he had this information but it is certain that being the commander that he was he would not venture forth with an army without knowing his probable route. Most certainly, the only map of the Mediterranean (Strabo, trans. Jones, 1999) made two centuries after the invasion is nearly blank north of Massillia (Marseilles) with a distorted Adriatic oriented nearly east-west (see Mahaney, 2008a, Fig. 2.2). Clearly beyond probable sketch maps and recollections of agents, Hannibal probably fixed on the lowest of all passes across the Col de Genèvre (~2000 m), generally considered a main Gallic artery, later named Pompey's Pass when he led Roman armies into Gaul during the Civil Wars.

If one assumes Hannibal intended to take the Durance route to the Col de Genèvre he would have had to either swing his army eastward from the Rhône to take the Durance north or follow the Rhône to the Drôme confluence stopping near Orange to meet with lowland Gauls whom Polybius (III, 49) affirms he had made a previous arrangement for resupplying his army. Thus, it is highly unlikely that the army would resupply at Orange and trek northward to follow the Isère route and even so, if this route is preferred, one is left wondering where the first mountain pass might be located before encountering the long defile along the final approach route to the high col. Further, if, as Polybius (III, 50) asserts, this first obstacle had to be taken in a night operation, the Gauls abandoning the high pass; the only possible cols are in the Dauphiné Alps—Col de Cabre (1193 m asl) and Col de Grîmone (1318 m asl)—and only the Grîmone pass fits the topographic assessment offered by Polybius (Mahaney, 2008a).

Once across the Col de Grîmone and into the Durance valley with local tribes in tow, Hannibal was faced with mounting obstacles, the followers and the Durance crossing. The followers gave up hostages and cattle but Polybius notes their friendship was uncertain and no doubt his scouts probed both the Guil passage and the Col de Genèvre. We shall never know why Hannibal diverted from the Genèvre to the Guil Valley, but if the Allobroges held the former, it is certain he would have sustained heavy losses trying to force passage. Polybius is certain that Hannibal was with his rear guard (often his position on the trail) making it likely, Maharbal, his second-in-command was with the vanguard and may have made the decision to follow the Guil River. Apparently the army deviated from the Durance following the Guil River into the major defile described by Polybius, an 18-km long gorge with steep cliffs where the army was trapped by an assault on the rear echelons and from the flanks, apparently with the elephant corps and the cavalry up front, Gallic mercenaries in the middle and Hannibal with African and Spanish contingents in the rear. It was the Gauls who got the worst of the assault (Mahaney and Tricart, 2008), which lasted for a day, Hannibal regrouping his troops near a 'certain bare rock' Polybius, III, 53) just inside the gorge entrance. The only large rock thus located is within 2 km of the gorge entrance as described by Mahaney (2008). Because this account is the only one matching the present topography with the ancient texts, it is probable that Hannibal marched from the Drôme to the Durance and into the Guil basin. Following the initial engagement in the lower foothills, the only such large and long gorge is the Combe de Queyras as described by Mahaney (2008a), all other approach routes leading to Mt. Cenis and Col Clapier lacking a long narrow defile (see Mahaney et al., 2008c, 2010c).

Putting the two main sources of the invasion together, and considering that Livy never left Padua and wrote 180 years after the invasion, while Polybius followed the invasion 67 years after the event, following interviews with people who, he says, had taken part in events. Polybius likely traveled quite possibly with sketches from Silenus in hand, and it is he who provides the most convincing topographic, environmental, and possible stratigraphic information related to the mountain crossing. Whereas the topography is described in general terms by both historians, it is Polybius who provides more detail on the approach defile, snow, frozen ground, view from the col, the rockfall blockage (Fig. 3) of the exfiltration route and the regrouping area below the rockfall. It is Polybius' rockfall description of a two-tier rock system that places him within the ranks of the stratigraphic elite of history as he clearly understood that one deposit was older, the second younger. In translation, at least, he is quoted as interpreting one deposit overlying another, a stratigraphic succession clearly seen even today based on weathering differences displayed on cobbles and boulders in the mass wasted deposits (Mahaney, 2008a; Mahaney et al., 2014).

Polybius was presumably an accomplished military officer but his observation places him within a group of extremely keen interpreters of the landscape. Few, even today, would venture across the Traversette rockfall (Fig. 3) and recognize two superposed rock deposits distinguished principally on weathering features and soil morphogenesis. Perhaps such weathering features as color and oxidation states of clasts in the two deposits were likely more apparent in Polybius' time than today since the youngest mass would likely have lacked major lichen cover and oxidation effects would have had an age of only a few centuries if the observations of Mahaney (2008a) are correct. Thus, key environmental parameters comprise an environmental matrix, construed from Polybius and Livy, the former relying on those works available to him from afar including most likely the journals of Silenus who accompanied Hannibal as topographer and scrivener, thin with particulars as they are. These parameters include the following:

First, the crossing of the Durance and decision to follow the Guil River, if made by Marhabal, follows from assessments by Basil Hart (1967) who mentions the unusual authority delegated to Marhabal by Hannibal who often led the vanguard. We shall never know who made the decision to tackle the highest route but it is certain that Hannibal did not want to fight the Allobroges (Polybius, III, 52). The defile leading to the high slopes, following a lengthy survey of all possible approach routes (Mahaney et al., 2010b) targets only one candidate, the Combe de Queyras (Mahaney, 2008a), the only gorge with the right length of ~18 km. No other approach route offers the same topographic obstacle with steep walls providing the Gauls with a rock source to be hurled at the Carthaginians (Mahaney, et al., 2010b).

Second, snow accumulation, assuming the crossing was in October, 218 BC, it is not unusual in the Alps. The snowline was probably similar to today (Neumann, 1992) but a sudden snowfall may have produced melting followed by freezing at the ground/snow interface which would make footing difficult. Such a snowfall might extend as low as 2000 m which indicates the army's first contact occurred above the long defile, most probably near the present Chateau Queyras. It is possible higher up that soldiers slid on sporadic permafrost but this is uncertain as no permafrost was encountered during later investigations (Mahaney et al., 2007a; Mahaney, 2008a).

Third, regrouping area in the upper valley, unidentified until Mahaney et al., 2017a, 2017b, 2017c, discovered churned-up beds in alluvial mire sediment (Fig. 4) at 2800 m dated to within the Hannibal window of 2168 cal yr BP. These beds (Mahaney et al., 2017a), at approximately ~40 cm depth, with ~15 cm amplitude, contain faecal biomarkers [(5β-stigmastanol and the bile acid deoxycholic acid (DCA)] (Mahaney et al., 2017b) related to horse and mule manure with roundworm eggs and bacteria, the latter belonging to microbe groups of Firmacuties and Clostridia related to gut release from horses and mules (Mahaney et al., 2017b). These findings show the passage of thousands perhaps tens of thousands of animals and potentially humans. Studies of the magnetic susceptibility of sediment within the French mire showed a slight increase in the churned-up beds of several sections (Mahaney et al., 2017c) which may relate either to abnormal concentrations of magnetite or to the presence of weathered artifacts. In any case the mire should be subjected to a metal detection survey and possibly to GPR (ground penetrating radar) investigations. As well, lowland areas behind the Younger Dryas moraines adjacent to the Guil mire should also be subjected to similar surveys.

Fig. 4. French mire at 2850 m astride a tributary to the Guil River (Photography by Pierre Tricart).

Fourth, the col from which Hannibal looked across the plains of the Po. Investigations at all possible crossing places indicate the Traversette col is the only passage which gives a long view, on a clear day nearly to Milan (de Beer, 1969). The two cols adjacent to the Traversette—Col Agnel and Col de la Croix—offer restricted views cross country and do not look down upon the Pol plains. Because Polybius definitely targets the Po river plains as the exfiltration point, thus excluding the Dora Riparia leading to the Po from the Clapier and Cenis cols some 50 km to the north. Polybius (III, 54) states Hannibal is said to have called his men to the col and pointed the way toward Rome to reassure them, but he could not have amassed the entire army on any of the cols, and the Col de la Traversette itself could barely hold 100 soldiers, so he must have addressed his key lieutenants not the entire army.

Fifth, the rockfall (Figs. 2 and 3) in question can only be found below the Traversette col, a mass of rubble matching closely to Polybius' estimate of 250 m wide and comprised of two stages of development, one older and the other and upper one younger. While Livy mentions that Hannibal fired the rockfall to heat and split boulders, Polybius is mute on the subject, indicating the firing event never happened. Further, following an extensive investigation of the rockfall surface, clasts embedded in the deposit surface did not reveal any vestige of firing, no carbonized material (Mahaney et al., 2008c, 2010b). It appears the rockfall firing episode described by Livy is mere fiction, and more to the point, where and how would wood be obtained as firing material by soldiers close to starvation (Bagnall, 1999) and with timberline far below the rock mass.

Sixth, the regrouping area could lie below any one of a number of possible cols of passage but the likely area below the Traversette is on a bedrock plateau floored with mire and coalescing alluvial fans (Fig. 5) at ~2000 m asl, the latter of which reveal a churned-up bed similar to the alluvial mire on the French side (Mahaney et al., 2018a). That the lee side area has been used for centuries is obvious from a stone house, complete with animal quarters and a urine trough oriented north-south, draining onto slopes on the north flank of the Po river and stone walls at around 2250 m used to pen animal stock as described by (Mahaney et al., 2010a).

Fig. 5. Upper Po valley mire and coalescing alluvial fans showing core and section sites V21, V21A and V21B. Photography and site annotation by Peeter Somelar; figure after Mahaney et al. (2018a). Data from these sites is interpreted in Mahaney et al. (2018a).

Seventh, most historic arguments have mentioned Hannibal's famous elephants but few have questioned the ability of elephants to make the journey over the Alps. John Hoyte (Hoyte, 1960) of Oxford

University experimented with an elephant crossing Mt. Cenis showing that it was possible and that Hannibal could easily have managed at least the crossing to the north at lower elevation. However, elephants are known to work at high elevations as documented by Mahaney (1990) reaching elevations above 4500 m. Thus, crossing the Traversette col at ~3000 m asl would have been possible although difficult given the narrowness of track in place and lack of forage. The remains of Hannibal's elephants have been found in the Arno terraces near Florence (Romano and Palombo, 2017).

Eighth, dating the evidence required using *relative* vs. *absolute* methods. *Relative age-dating* methods rely on criteria that relate one topographic /geomorphic entity against another using, for example, height of one terrace over another (Mahaney et al., 2016b), the difference in elevation a measure of the erosion event followed by a deposition (filling process). In other cases, changes in strength of weathering and soil development have been used to establish relative ages in many alpine areas (Mahaney and Kalm, 2013). Also, if different in time the older deposit is expected to carry stronger pedogenesis, that is, a more complex weathering profile compared with the younger deposit. One cannot say for certain what time is involved, only that a soil (e.g. paleosol) in the older terrace represents greater time for development. Also, hearths in deposits that may have been used as bivouacs for a long time may contain stratigraphic evidence belonging to ecologic disturbance, possibly the Hannibal event, and may contain charcoal material that could be dated by AMS C14. All soil descriptions follow the Canada Soil Survey Committee (1998) and the USDA (Soil Survey Staff (1999). All soil and sediment colors reported in the literature are based on the color chips of Oyama and Takehara (1970).

The Traversette rockfall, a case in point, illustrates how surface weathering features (i.e. color of surface clasts) resulting from physical and chemical alteration that distinguishes the two deposits could be used to separate deposits in time (Mahaney et al., 2014). In this case we know the older lobe of debris is >12.8 ka because it contains cosmic material correlated to the black mat event (Mahaney and Keiser, 2013) and the paleosol within can be correlated to Late Glacial (15 ka-12.8 ka) sediment); the younger lobe contains weathering clastic materials related to weathering and soil development considered to be of middle Neoglacial (~3.0 ka) age; thus the sediment seen by Polybius must be >2.2 ka. Polybius, of course was guided by the color differential which clearly delineated the two deposits on the basis of chemical alteration products (i.e., oxides and hydroxides) and illustrates his extraordinary powers of observation. My interpretation of the rockfall and its importance in the route interpretation was criticized by Kuhle and Kuhle (2012) who favored along with others the northern route via the Col de Clapier, an entrance to cis-alpine Gaul for which there is little evidence (Mahaney, 2008a). The evidence for the Traversette rockfall as the key site supporting the southern route of de Beer (1969) was summarized by Mahaney (2013).

To obtain *absolute ages* on materials in this case relies only on radiocarbon (Mahaney et al., 2017a, b, and c), which is used to date relict organic material buried in section. Because the half-life of the ^{14}C isotope is 5710 yrs most of the recovered organic material relevant to solving the Hannibal enigma is well within the first one-third of the first half life decay process, which means that providing there is no contamination of samples one can expect accurate dates with low standard deviations. However, since relevant samples are within ~50 cm depth there is always the possibility of leaching of younger organic carbon downward in section, thus producing younger ages. Couple to this, the possibility of ground water influx into older sediment, the addition of younger organic carbon may produce the same effect. We may get around this by careful scrutiny of the standard deviations for each date to insure the standard deviation is <3% or approximately ~60 yr or less. The maximum age possible for conventional radiocarbon dates is ~40 kyr; this increases to ~70 kyr for AMS (Accelerator Mass Spectrometry) dates, with somewhat smaller standard deviations for the latter method. All AMS radiocarbon analysis and date assignment follows Bronk Ramsey (2009), Bronk Ramsey and Lee (2013) and Reimer et al. (2013).

An inventory of possible sites for radiocarbon dating along the targeted routes produces alluvial terraces covered with surface soils and buried paleosols, alluvial fans along valley sides, alluvial mires, and possible hearths. In most alpine areas of the world bogs and lacustrine plains often provide a means of obtaining bog-bottom dates which are, at best, minimum ages on organic remains on deposits within which such materials are found. Once a depression is formed it may infill with inorganic sediment for a time (ecesis period), before which recognizable organic remains accumulate which can be dated, hence, the minimum age. Lacustrine plains, reacting to lake level fluctuations may contain buried soils that may be dated by ^{14}C but these are not present in suitable positions to add to the Hannibal story. To add hearths to the list requires one to overcome the speculation that requires one to think that Hannibal's army would not pass up a site like this and some assurance that Hannibal actually took the route specified. The same applies to alluvial terraces and with these surfaces the prospect of organic retention is not great which means large samples are required to obtain even minimum organic residue that might be obtained for dating. Alluvial mires present both in the upper Guil and Po catchments present the best options for dating because water velocities are low and retention of weathered organic sediment is great combining to preserve disturbed sediment beds from some previous episode of bioturbation such as disturbance from a foraging army. In the case of the upper Po drainage the presence of an endangered species of salamander required that all sampling be relegated to alluvial fans away from mire sediments that might have yielded better results both in terms of the physical and stratigraphic evidence (Mahaney et al., 2018a).

Pulling cores and digging sections in alluvial sediment produces planar beds aligned horizontally with the earth's surface so that variance in flow regime and or changes in source sediment produce sorted sediment even in beds with high organic input. Cores of 50-70 mm diameter limit the amount of recovered material for dating and chemical analyses whereas sections produce open faces with widths of 50 cm + allowing collection of material for replicate dating where necessary and higher weight material for laboratory analyses of various kinds. The analyst expects to collect downward from the surface into progressively older beds and if bioturbated (churned up) beds are encountered such disturbed beds will produce wavelengths and amplitudes of various dimensions, physical evidence normally not seen in cores. In the case of the French vs. the Italian sediment complexes one might expect the softer French sediment to deform to a greater degree than the Italian coarser sediment which is approximately what happened. The French sediment sites showed an approximate center of disturbance at 40 cm ± 15 cm amplitude whereas the Italian sites showed disturbance centered at 50 cm ± 10 in two out of three sites; 60 cm ± 15 cm in the third site. The variation in depth of disturbance is explained by differences in sedimentation rates partly the result of a wetter climate in Italy compared with France.

Aside from the loss of planar beds nearly horizontal to the Earth's surface common to mire and alluvial fan deposits (Mahaney, 1990), sediment within the bioturbated beds is commonly much darker (addition of faecal matter and reworked humus) than variegated colors encountered up or down section from the disturbed beds. Common color ranges within the bioturbated beds are: 10YR 1/1, 2/1; 7.5YR 1/1, 2/2, 2,2; to 5YR 1/1,2/1. YR refers to hue, the dominant wavelength, where decreasing color refers to strengthening of the yellow red color. The two numbers that follow refer to brilliance with increasing value from dark to light, and chroma, purity of dominant wavelength, which increases with decreasing white light. Common wavelengths for young sediment such as in the upper Po Valley are 10YR (yellow red) and 2.5Y (yellow), the former for various degrees of weathering and the latter for fresh, unweathered sediment. To use the analogy of a cube to which hue, value and chroma are measured along three edges (Millar et al. 1966), each color notation represents a point in the cube, i.e., the Munsell notation. Within each major hue represented here, a lower value and chroma represent a darker and more carbon-rich sediment. For lithology in the field area, we relied on geological mapping by Tricart et al. (2003).

One of the great assets of working in the Guil and Po valleys rests on the detailed bedrock mapping (Tricart et al., 2003) carried out by Pierre Tricart and his associates from the Institute of Geology, University of Grenoble. Having bedrock control for all sites explored in this area insured that lithologic relationships could be worked out in the laboratory prior to engaging in field work.

Finding the churned-up bed is one part of the task, dating the transition zones to younger beds up section and older planar beds down section, and explaining the greater than 2168 cal yr BP dates within the bioturbated mass still another. The boundaries of the bioturbated mass are so diffuse that the relevant radiocarbon dates may not truly reflect start up and shut down of the bioturbation process even though the two dates should be approximately the same, that is, representative of the x number of days required to produce the bioturbated bed. To further complicate the dating process it is necessary to produce a string of dates from near the surface to approximately the top of the churned-up bed which is a hit or miss proposition as shown in Fig. 5 that relates to section V21A in Mahaney et al. (2018 a) where the upper boundary is ~40 cm, the lower boundary at 55 cm but with some variance given the magnitude of disturbance.

4. INTERPRETING THE PROOFS

The lead up to the only possible defile along the approach route, the Combe de Queyras, is along either the Drôme River from the Rhône or from the south along the Durance. The southern route of some 150 km from the Durance/Rhône confluence does not lead to a col described by both Polybius and Livy but the Drôme approach does end at the Col de Grîmone in the Dauphiné Alps, the topography of which matches the landscape where Hannibal himself led a night operation to secure passage. These lowland routes have been thoroughly discussed by de Beer (1969) and Proctor (1971) as to likely diversions but the Drôme route would take Hannibal close to the Col de Genèvre (~2000 m), his likely intended col of passage.

As Hannibal's army approached and crossed the Durance, Hannibal was followed by the Allobroges who threatened his rear echelons (Polybius, III, 52). The question of why the Carthaginians diverted through the Guil valley from the Durance instead of marching towards the Col de Genèvre is uncertain but what is certain is that Hannibal was with the rear guard and the army, often led by Maharbal (Hart, 1967) who, according to Polybius, was informed of other Allobroges massing at the target col. Polybius is on record saying he did not want to fight the Allobroges, so it is possible the order to move through the Combe de Queyras came from Maharbal, Hannibal having his energies directed to the rear. If this is correct, it is odd if not unusual that the flanks were not protected adequately, because once into the defile presented by the Combe, the Gauls unleashed a ferocious attack that nearly overran the rear of the army (Polybius, III, 53). Because the elephants and cavalry were up front it was the Gallic mercenaries who caught the brunt of missiles and rocks hurled from the high ridges astride the Combe, the result being that Hannibal suffered heavy losses from what appears to be an enfilade attack a tactical maneuver similar to what he himself later used at Trasimene against the Romans in the Apennines (Mahaney and Tricart, 2008), a more modern example coming from Lee's attack on the Union Army at Gettysburg during the American Civil War.

Investigations carried out in the Combe de Queyras over the period 2002-2010 by Mahaney and Tricart (2008) pinpointed unusually large accumulations of boulders and cobbles along and at the base of the northwestern wall with the Guil River to the southeast. It would appear that even in Hannibal's time the approach was to the west of the river but recent flood control efforts may have rearranged some of the rubble deposits so finding artifacts in this mass would prove difficult and probably impossible.

Following the Guil River toward the high col, the only camping or regrouping place is between 2400 and 2650 m alongside the main drainage and a tributary that passes the G5 alluvial mire sites (Fig. 4) investigated by Mahaney et al. (2017a, 2017b and 2017c). To the south of the G5 sites several low-lying flat lacustrine plains offer some forage opportunities that were likely used by the Punic forces as they reformed following the battle below in the Combe de Queyras. Attempts to section two of these sites to the south of G5 (Mahaney et al., 2017c) produced inconclusive, results indicating the ecologically disturbed beds are likely deeper than ~1 m. If, as Polybius (III, 54) indicates, the army camped in snow, some of these depressions were probably used as water sources and even today the main Guil river drains the south side of the valley and would have provided a valuable source of water. More to the point, given the faecal matter and microbe analysis carried out at the G5 site (Mahaney et al., 2018b), which indicates widespread accumulation of animal and presumably human defecation, the entire moraine complex at 2400 to 2600 m asl in the upper Guil Valley is probably laden with metagenomic DNA and fossil faecal matter related to Hannibal's Army.

Reaching the Col de la Traversette at ~3000 m on a clear day, one can see across the Po plains below to some distance, possibly as far as Milan, as de Beer (1969) has stated. The usual view from below the Col de la Traversette is obscured by clouds as illustrated on the cover of *The Warmaker* (Mahaney, 2008b). Other route passages to the north at Col de Clapier and Col de Mt. Cenis have limited views from the summit and all look down upon the Dora Riparia which joins the Po River where Hannibal sortied against the Roman Army of Scipio whence he made contact, first at the Ticinus and latter at the Trebbia before retiring into winter quarters to the south.

The main proof for the Traversette Route is the blocking rockfall at 2600 m, the doublet deposits of such, the oldest lobes dating to at least 12.8 ka because they carry the black mat signature (12.8 ka) seen with microscopic analysis carried out by Mahaney and Keiser (2013) dating the early accumulation of rubble to the Late Glacial and well before Hannibal's time. The younger rubble accumulation that covers nearly three-quarters of the rockfall area is most likely of middle Neoglacial age judging by weathering features and soil morphogenesis that compares favorably with soil research carried out previously by Mahaney (1991). There is no similar rockfall deposit on the lee side of the Alps that would stop an army, only minor accumulations of rock rubble below all other passes (Sodhi et al., 2006).

5. ALTERNATIVE HYPOTHESES

Acceptance of the premise of both Polybius and Livy that Hannibal's army foraged in the catchment below the two-tier rockfall for a period of five days, such activity should have ravaged the upper valley and be recorded in the alluvial fan sediment recorded there. Any existing soil would have been grounded up and mixed with sediment in situ and imported by animal action. Because the surface soils (mostly Ah horizons) at all three sites are similar (about 12 cm thickness with A (Ah), C, Cu horizons, classed as Entisols (Soil Survey Staff 1999) or Regosols (CSSC, 1998), correlation with similar pedons in the upper Guil Valley (Mahaney et al. 2016) suggests these profiles are young and have been in situ for only two centuries or less. Both soil suites date to the end of the Little Ice Age (less than 170 yr), and their existence further suggests the soils have been protected from flooding that may have occurred since that time. Deeper into the three sections of the upper Po river valley and the multiple sections of G5 in the upper Guil valley of France darker beds encountered suggest periodic or aperiodic attempts to produce Histosols or soils with dominant organic compounds relative to inorganic sediment. However, because these organic beds lack oxidized horizons, it appears such attempts, although possibly long-lived in some cases, did not produce pedons.

Alternative testable hypotheses to bioturbation (churning) of sediment caused by Hannibal's Army might be: (1) upper flow regime flooding; (2) earthquake vibration; (3) transhumance; and (4) soil cryoturbation. The upper Po Valley is susceptible to extreme climatic events originating out of the Adriatic, as illustrated in 2008 when excessive precipitation induced intensive mass wasting and flooding in the form of debris flows that inundated valleys, and buried deposits up and down the Western Alps from Mt Cenis all the way to the south of Mt Viso (Mahaney et al. 2010a, 2010b). Such flooding events produced well-sorted and stratified sediment successions lacking the mixed-sediment character of the bioturbated beds seen in the French mire and in the upper Po sections described here. Whereas turbulent flooding events are possible and cannot be totally discounted, the available evidence indicates that bioturbation is the process that produced the observed sediment disruption. As reported by Mahaney et al., (2018a) particle size tests on a random collection (n = 6) of small samples taken from the churned-up bed in V21A in the upper Po valley show extreme variations in texture ranging from coarse sands (sometimes with pebbles) to fine silts and clay with no sorting visible. Water-sorted sediment recovered from alluvial/colluvial fans and lake beds (see Mahaney, 1990) follow the principle of horizontality, that is, beds are parallel with the Earth's surface. Unless disturbed by high-velocity currents, such as extreme flooding that occurs with jökulhlaups etc. or moraine bursts, such bedding is nearly horizontal with the Earth's surface. Exhaustive studies of Holocene alluvial fans on Mt Kenya (Mahaney 1990) failed to produce distorted bedding despite the presence of active glaciers during postglacial time.

Freeze–thaw processes in resident soils might produce convoluted beds or horizons which are not parallel in extracted cores or in dug sections excavated in the alluvial fans. Such convolutions usually leave beds or laminae intact, that is, upturned but lacking a disrupted or mixed quality which is plainly evident in the churned-up beds described here (Fig. 6). In any case, heavy snowfall in the Western Alps provides an insulating medium that may counteract freeze–thaw processes in underlying soils (for examples of Cryosols, see Mahaney and Kalm, 2013).

Transhumance might be expected to produce sediment disturbance and it is an activity known to have occurred in the upper Po Valley, as in several Italian valleys, over several centuries, but no record of churned-up or bioturbated sediment exists above the proposed

Hannibal beds identified at c.2200 cal BP in the subject area. Indeed, while transhumance has been prohibited in the upper Po Valley since the Second World War, the surface soil profiles in resident alluvial fans—V21, V21A and V21B—lack any sign of physical disturbance, which supports similar evidence reported in the upper Guil Valley of France, all this despite the ongoing practice of transhumance occurring every year (Mahaney et al. 2016, 2017a). Linking the churned-up beds in cores and sections in the upper Po Valley with the Hannibal event of 2168 cal BP means there is a time correlation between the churning event and the reconnaissance of the Hannibalic route in the upper Po Valley, Italy postulated passage of Hannibal. However unlikely, the coeval relation between the churning event and high-resolution dating may relate to some other anthropomorphic event not recorded in history. The churning event may also be partly related to menacing Gallic tribes following Hannibal after the altercation in the 18-km defile, as described by Polybius (Polybius/Scott-Kilvert 1979, III, 53; surface analysis by Mahaney 2008a). It remains for DNA analysis to link firmly recovered microbes and helminth parasite eggs with Spanish and/or North African animals.

With extremes of transhumance, freeze-thaw and upper-flow regime flooding sidelined as probable causes of the churned-up beds, vibrations caused by earthquake activity might also be expected to produce dislocated materials but with bed-to-bed or lamina-to-lamina stratigraphy, which is clearly lacking in the disrupted beds of the sediment stack reported by Mahaney et al. (2018a). Similar experiments using vibration tables have illustrated the effects of earthquake activity on sediment sorting (Miyamoto et al. 2007), forcing dislodged sediment into discrete groups. Whereas earthquake activity in the Western Alps is known to be an ongoing process, the deposits under investigation here show little sign of full-scale vibration or neotectonic activity.

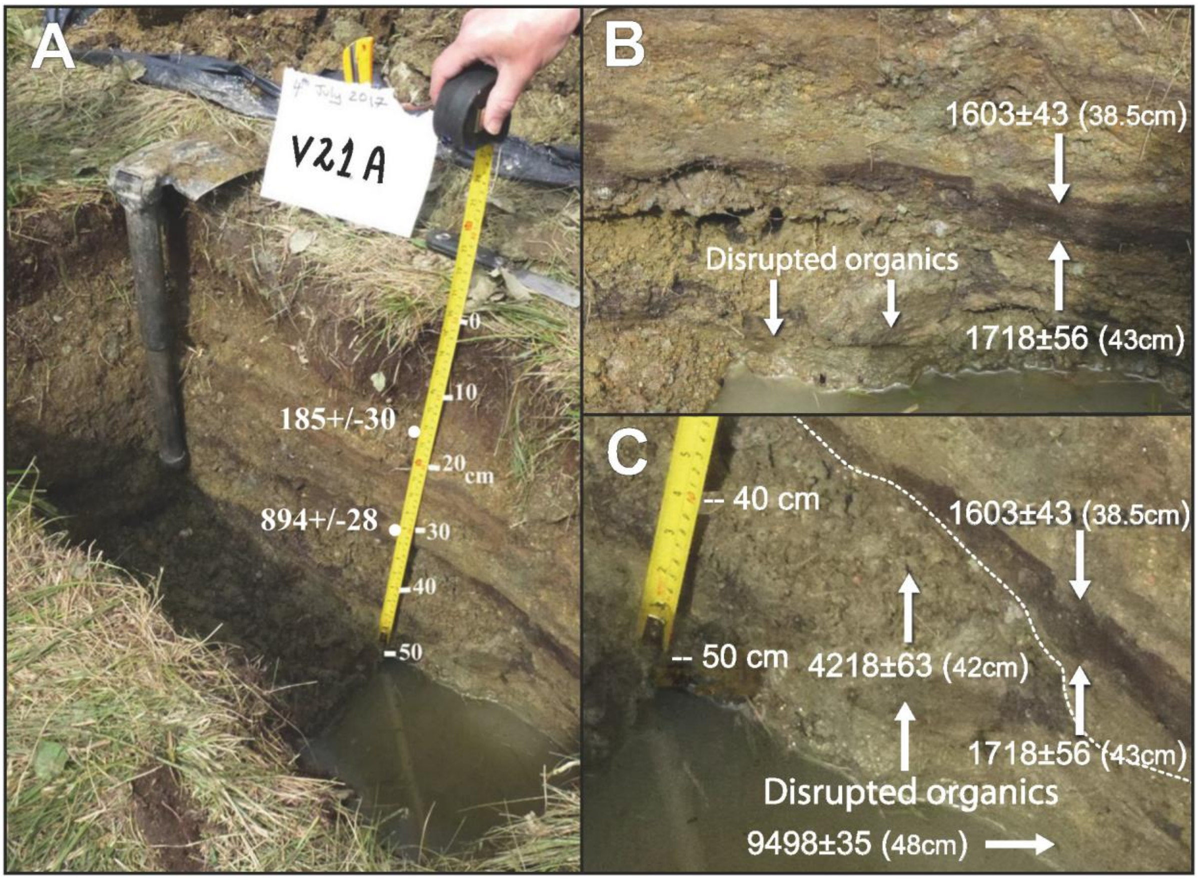

Fig. 6. Radiocarbon dated beds in section V21A showing the age progression from near the surface to approximately ~40 cm depth, the transition from time of normal sedimentation to the onset of massive ecological disturbance, i.e., the churning event. The >2168 cal yr BP dates represent sediment transported into the churned up morass by animals, humans or natural processes such as surface runoff or aeolian influx. Figure after Mahaney et al. (2018a).

Competing routes for the Hannibalic invasion are shown in Fig. 1 (Mahaney et al. 2017a), although various other authors (i.e., Guillaume, 1967; Proctor, 1971) have argued for other cols adjacent to the Traversette and Mt Cenis, without linking topographic and geomorphologic evidence to support their claims. Time/motion analyses (Mahaney 2008a) of the northern (Cenis) versus the southern (Traversette), show the Traversette route to be slightly shorter but with more rugged terrain, longer over the less rugged Mt Cenis. This assumes that Polybius clearly differentiated between the Po plains and the plains adjacent to the Dora Riparia (a northern tributary of the Po River). The only route leading to the Po plains is over the Traversette. All variations between elevations, snowline, presence of frozen ground, long defile on the approach to the mountains and a large rock just inside the defile entrance have been discussed by Mahaney (2008a).

6. CONCLUSIONS

The various stages of reconstructing the Hannibal enigma illustrate just how information buried in the classical literature might be reconstructed to provide an environmental matrix that can be tested using various scientific analyses. In this case, work started with a topographic and geomorphologic base that could be used to provide time/motion analysis to establish movement of the Punic Army, results indicating that of the three proposed routes outlined in Fig. 1, only the middle route is the longest, the northern and southern routes almost identical in time distance but not regarding physical obstacles. The southern route across the highest of all passes with the most rugged terrain would require extra time but just how much is unknown. The battle in the approach defile and construction through the rockfall placed heavy burdens on the army, especially since as Polybius indicates they lost much of their provisions and this must have put a strain on animals, principally upon the elephant corps.

Beyond the initial phase, expertise in a variety of fields was required to put numbers to the allotted time of crossing requiring mathematical/statistical studies and astronomical calculations as to the amount of moonlight, and timing of movement with the hunter's moon (Mahaney et al., 2008c). Excavations of mires and hearths required pedological, geochemical, radiocarbon and palynological inputs from a variety of co-authors, all of which are listed on numerous papers in reference lists as noted in this paper. While permits were obtained to carry out the geological and biostratigraphic work, no attempt was made to obtain archaeological input beyond what is outlined in various papers. The only artifacts obtained are in the form of microbes and faecal matter obtained from sections dug in sediment piles in various places and from cores taken in similar settings. The main findings of this research affirm the interpretations of Sir Gavin de Beer some decades ago that Hannibal for one reason or another took the highest and most difficult route into Italia across the Col de la Traversette. Indeed, even Polybius is on record saying that Hannibal took the highest route, later named in order of position south of the Col de Genèvre, Hannibal's pass. For the last two millennia, the Traversette has been known as 'Hannibal's Pass' and even during WWII, SOE (Special Operations Executive of British Intelligence) referred to Mt. Cenis as Napoleon's Route, the Traversette as Hannibal's Route in secret documents recently made public (Mulley, 2012).

Polybius is also on record using the phrase—*tas hyperbolas tas anōtatō tōn Alpeōn*—the highest pass of the Alps (personal communication, J. Lazenby, 2007) to describe the pass used by Hannibal. Thus, whatever historic postulate of possible or impossible routes is put forward by various authors, this forensic analysis of all environmental parameters described in the ancient literature, plus the microbial evidence presented here, is heavily weighted in favor of Sir Gavin de Beer's southern route across the Traversette. Despite the single-file approach off the col to the permanent snowbank above the discarded Italian army barracks at ~2650 m asl, the only route assigned by the key environmental parameters discussed herein, is the Traversette, negotiated with difficulty by the Hannibalic Army and marking a key event in antiquity.

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