Mediterranean Archaeology and Archaeometry, Vol. 17, No 1, (2017), pp. 23-35

DOI: 10.5281/zenodo.258081

NOTES ON MAGNETIC SUSCEPTIBILITY IN THE GUIL VALLEY ALLUVIAL MIRE CORRELATED WITH THE PUNIC INVASION OF ITALIA IN 218 BC

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Received: 23/08/2016
Accepted: 14/11/2016
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ABSTRACT

The enigma of Hannibal's route across the Alps in 218 BC is one of the most enduring questions of antiquity. Many authorities, some of whom have never ventured into the mountains, have argued for various preferred crossings of the Alps. Earlier efforts to identify the route focused on the two-tier rockfall and regrouping area on the lee side of the Range, originally described by Polybius in his *The Rise of the Roman Empire*, by Livy in *The War with Hannibal*, and later by Sir Gavin de Beer who searched out the topography and stream dynamics in the area of several projected crossing routes. Recently, attention shifted to the alluvial mire in the upper Guil River after cores and sections (sites G5 and G5A, Mahaney et al., 2016a) revealed the presence of churned-up or bioturbated beds, called the Mass Animal Deposition (MAD) layer. At approximately 45 ±15 cm depth, the top of the MAD layer contains abundant bacteria belonging to the class *Clostridia* that are found in the mammalian gut and fecal deposits, all dated by AMS ^{14}C to 2168 cal yr BP (i.e., 218 BC with a 95% confidence interval). Samples for magnetic susceptibility collected from three additional sections (G5B, G5C and G5D) carrying the churned-up beds reveal heightened magnetic intensity within these bioturbated sediments that is suggestive of high magnetite content, one form of iron that often was used to cast weapons in ancient times. Magnetic susceptibility levels are highest within the churned-up beds with minor exceptions in two of the three sections analyzed, possibly indicating the presence of weathered tools, implements or weapons lost or discarded. The available data is sufficient to suggest that a GPR survey of the entire mire might well lead to recovery of the first artifacts from the invasion that would shed enormous light on the culture of ancient Carthage.

Keywords: Hannibalic War; Invasion route; Magnetic susceptibility.

1. INTRODUCTION

In 218 BC, Hannibal's army traversed the Alps into Cisalpine Gaul (Northern Italy). For more than two millennia afterwards, there has been ongoing debate and discussion by hundreds of historians and archaeologists of the approach route used by Hannibal's army to cross the Alps (Livy, 1965; Proctor, 1971; de Beer, 1974; Polybius 1979, to name just a few), as well as speculation about the possible cols, identified as the high summits, used by the army for passage into Italy (Freshfield 1886, 1899; Dodge, 1889, 1891; Wilkinson 1911; de Beer, 1956, 1967, 1969, 1974; Dion, 1962; Connolly, 1981; Huss, 1985, Cottrell, 1992; Seibert, 1993; Lazenby, 1998; Bagnall, 1999, and Lancel, 1999). These early interpretations are based on historical interpretations with sometime reference to topographical features. Lately geoscientists, chemists and biologists have endeavored to narrow down sites worth historical archaeological exploration (see Mahaney 2004; Mahaney and Tricart, 2008; Mahaney et al. 2007a, 2008a, 2008b, 2008c, 2010a, 2010b, 2010c, 2014, 2016a, 2016b).

The main invasion passages are referred to here as the southern, northern, and intermediate routes, as shown in Fig. 1A (Hart, 1967; Proctor, 1971; de Beer, 1974). They come with offshoots, sometimes preferred by some, for one reason or another, because they shorten the traveling distance to the Po Valley or have a particular topographic feature described by Polybius.

The northern route parallels the Rhône River to the Isère River, past present-day Grenoble along the Arc River to either the Col du Mont Cenis (2083 m) or Col Clapier (2497 m), finally exiting into the Dora Riparia west of Torino (Turin in Fig. 1A). The intermediate route follows the same initial course as the northern route, then west of the Pelvoux Massif to join the Durance River continuing towards the Col de Mont Genèvre (1830 m), exiting into the Dora Riparia.

The southernmost route follows the lower Rhône River valley northward to the Drôme River, thence east across the Col de Grîmone (1318 m; Alpes du Dauphiné) to the Durance Basin, through the Queyras (Guil River) to the Col de la Traversette, finally exiting through the two-tier rockfall similar to that described by Polybius (Polybius, trans., 1979) into the upper Po River catchment. The southern passage is the only route that bears a near complete match to Polybius who followed the invasion route into Italia some 60 years after the event.

Time-motion analysis of these three potential routes coupled with field investigations of each pass into Italia (Mahaney, 2008) revealed that while the southern route is the most direct, it is also the highest track into northern Italy from the Rhône Basin and perhaps the most difficult to pass. The question remains that while all authorities agree that Hannibal had to march with speed to cross the Alps before winter set in, why did he chose to take the higher route? Polybius (trans., 1979), the foremost primary ancient authority on the invasion, related that Hannibal did not want to fight the Allobroges (mountain Gallic tribe), and as the army marched to the Durance valley, it was the Allobroges who had been closing on his rearguard with another large force massing ahead near the Col de Genèvre. With Hannibal's unique relation with his cavalry commander (Hart, 1967), Maharbal, who often led the vanguard, it may have been he who decided that the Allobroges threat called for a detour into the Guil Valley toward the Col de la Traversette. Likewise, Polybius, who is the prime ancient authority, states definitely that Hannibal descended to the Po River Plains rather than to the Dora Riparia approximately 50 km to the north.

After two millennia of investigations, correlation of ancient topographic names with moderns ones, the question of the precise path over the Alps still remains unsettled. Previous arguments about the invasion route have relied on numerous historical renditions of events, not on physical evidence or environmental parameters (Mahaney, 2008), because no physical artifacts (nails, coins, buckles, implements or weapons etc.) have ever been found on any of the potential alpine routes. Even if artifacts are found, the specific identified path over the Alps could have been taken by Hannibal or by his brother Hasdrubal, who followed him eleven years later with a large army marching out of Spain (Proctor, 1971; Lazenby, 1998; de Beer, 1974).

In addition to traditional artifacts, organic compounds associated with people and animals may easily persist for several millennia and are relatively easy to detect, leading to the hypothesis that the Hannibalic Army with its vast numbers of horses/mules/elephants may have left organic evidence of their passage through the high col. We located a site in an alluvial mire at 2600 m asl along the southern search for pedological, palynological, paleobiological, biochemical and lipid biomarker evidence that might help determine if the site was along Hannibal's invasion route (Mahaney et al., 2016a, 2016b).

After successfully identifying gut-derived sterols, bacterial endospores, etc. at the site, we further sampled three sections for magnetic susceptibility within the churned-up beds to investigate the possibility of the presence of iron-based artifacts. Magnetic susceptibility (MS) is a dimensionless proportionality constant that indicates the degree of magnetization of sediment in response to an applied magnetic field.

Related to MS, the proportional difference between magnetic moment and magnetic flux density is termed magnetizability. It can reveal information about the presence of magnetic minerals or iron weapons/implements.

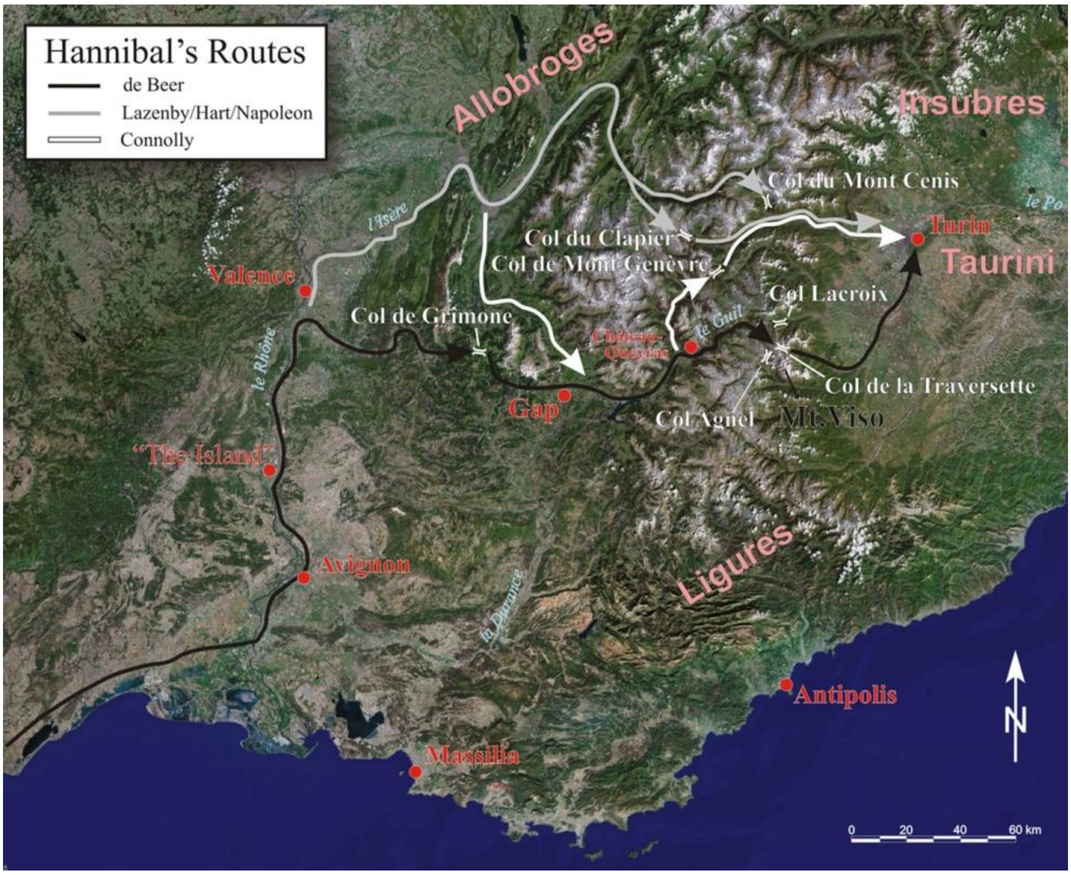

Fig. 1. A, Satellite image (courtesy NASA and USGS) shows the terrain of the western Alps and the three prominent invasion routes considered by most authorities to demarcate Hannibal's route into Italia in 218 BC; B, View of the G5 mire from the trail up to the Col de la Traversette. Slope in upper segment is the proximal slope of the Younger Dryas moraine C, paleomagnetic cylinder used to collect magnetization samples. From Mahaney, 2016.

1.1 Environmental factors related to the invasion

Several distinctive topographic landmarks related to the Hannibalic Invasion are identified in the ancient literature (Proctor, 1971, de Beer, 1974, Polybius, trans., 1979, Mahaney, 2008; Mahaney et al., 2014). These landmarks include a gorge along the approach route, 'certain bare rock,' col bivouac, presence of ground ice, view into Italia, blocking rockfall, fired boulders within the rockfall, and regrouping area. All these landmarks are common elements, but **not all** are found along each potential invasion route. However, the only route meeting two **key** historical descriptors—the rockfall and frozen ground—is the southern passage across the Col de la Traversette into the Po River plains of northern Italy.

Of all environmental factors used to identify the invasion route (Mahaney, 2008), there are two paramount lines of evidence. First, the superposed **two-tier rockfall** described by Polybius (trans., III, 54), and described by Mahaney et al. (2010c), provides strong supporting evidence for the Traversette Col. It is the most compelling evidence because it was viewed by Polybius directly when he followed the invasion path and it is the **only blocking rockfall** below any of the supposed cols the Punic Army might have used to enter Italia. After surveying all likely passes used by the Punic Army (Mahaney, 2008; Mahaney, 2010c, 2014) at 2600 m asl), the only such rockfall debris below all cols that could have blocked the Punic Army is located on the lee flank of the Alps in the upper Po Valley below the Traversette Col. More interesting, perhaps, is that of the many repeat histories published over the years, and with quotes from both Livy and Polybius, most workers have failed to focus on Polybius' mention of a **two-tier deposit**, one mass produced by two mass wasting events that blocked Hannibal's Army.

The account of the rockfall impediment possibly comes from a first-hand account by Silenus, (Hannibal's historiographer; Lancel, 1999) and Livy who maintained (Livy, trans., 1965, XXI, 37) that the rockfall provided such a barrier to passage by the animals–horses and elephants–of the army that Hannibal ordered the firing of large clasts to allow passage into the lower valley. According to this account by Livy, wood was brought to the site at 2600 m asl, the mass set alight, producing sufficient heat to physically disrupt and crack boulders that could not be moved by hand. Bagnall (1999) questioned Livy's interpretation, arguing that green wood could not be ignited easily, much less burn. Wood might have been available up to ~2400 m asl (Mahaney et al., 2010a) provided one might expect Hannibal's starving soldiers physically capable of harvesting/transporting it to the rockfall, a somewhat doubtful outcome. Not even Kuhle and Kuhle (2012), who mention the firing event, were able to substantiate how it might apply to the northern route across the Col du Clapier, their preferred route of passage for Hannibal into Italia. Previous work by Mahaney (2012) showed conclusively that while the rockfall described by Polybius exists below the Col de Traversette, there is no evidence that it was fired (Mahaney et al., 2007a). Despite a full survey of the entire mass, no carbonized/split boulders are resident in the rockfall mass (Sodhi, et al., 2006). Moreover, and most importantly, Polybius is **mute** on the firing event, and since he was the prime authority on the invasion route, the likely conclusion is that, despite its perpetuation, the firing never happened.

The second vital clue is the presence of permafrost, either sporadically or permanently frozen ground. Sporadic permafrost, where present today, is deeply buried in the Western Alps (Mahaney et al., 2007b), and a similar situation likely existed in Hannibal's time because today's climate is similar (Neumann, 1992). Thus, it is likely the major terrain obstacle of frozen ground referred to by Polybius (trans., 1979) was not permafrost, but rather discontinuous/sporadic frozen soil or firnpack (dense snow) covered with fresh snow. The Traversette Col, compared to the other mountain passes, is the only pass reaching to within the snowline (~2800 m asl) with discontinuous permanent snow (firnpack). At lower elevations of adjacent passes, the Col Agnel (2755 m asl) and the Col la Croix (2298 m asl), adjacent to Traversette (Fig. 1), provide somewhat shorter routes into Italy, but lack firnpack/discontinuous frozen soil, which is a prerequisite to identifying the correct col. Moreover, none of the other major cols—Clapier (2497 m asl), Montgenèvre (1830 m asl), Mont-Cenis (2083 m asl)—have permanent snow/firnpack or blocking rockfall, which is why de Beer (1974), and other researchers (Mahaney 2008), favored the Traversette as the route Hannibal used to cross the Alps. Even with elevations imprecisely known at the time, Polybius's (trans., 1979) description of the invasion route strongly suggests the Traversette as the crossing point into the peninsula, an inference supported by Varro's mention of the geographic order of passes from north to south in *De Re Rustica* (quoted by Proctor (1971)). In sequence, the passes are ordered geographically from north to south with 'Hannibal's Pass' lying south of the Col du Montgenèvre (Fig. 1). Moreover, reference to Varro's mention of the five cols, including Hannibal's Col as the highest, is quoted in Servius' commentaries translated in Savage (1934) and Livy's translator (de Sélincourt, 1965) identifies the Traversette as the col transited by Hannibal's Army. Polybius is also quoted as using the phrase 'tas huperbolas tas anōtatō tōn Alpeōn'—the highest pass of the Alps (J. Lazenby pers. comm. 2007), which is unreservedly the Traversette col.

In addition to the two-tier rockfall and presence of frozen ground described above, a third requirement for a successful passage into Italy is the presence of forage and sufficient watering holes for animals and humans alike. Assuming the Col de la Traversette is the route taken by Hannibal, as all topographic data indicate (Mahaney, 2008), the mire sites previously investigated [G5 and G5A – described by Mahaney et al. (2016a, 2016b)] and sites G5B, G5C and G5D analyzed here, would have provided an area of forage and fresh water for use by Hannibal's troops and animals. The mire evidence by itself presents strong supporting evidence that the southern route through the Traversette is the route taken by Hannibal.

2. MATERIALS AND METHODS

The alluvial mire of G5 sites (Fig. 1B) as described by Mahaney et al. (2016a) is composed of Histosols (Soil Survey Staff, 1999), essentially a wet peatland with fibric horizons down to ~30 cm and with underlying hemist horizons to ~70 cm where bedrock is encountered. No saprist horizon exists in the peat succession, the time frame of <4 kyr insufficient for decomposition to consume all or most of the organic residue. Sections were dug by hand, the profiles cleaned using army shovels and D-handled straight blades to reveal clean faces into which plastic p-mag cylinders of 1 cm^3 (Fig. 1C) were inserted at discrete intervals for magnetic susceptibility analysis using a custom-built magnetic susceptibility meter from Sapphire Instruments, model Sl-2B. AMS radiocarbon dating was carried out at 14CHRONO Centre, Queens University, Belfast, 42 Fitzwilliam Street, Belfast BT9 6AX, Northern Ireland. Calibrated radiocarbon ages were determined using the Ox.Cal system of Bronk Ramsey (2009), Bronk Ramsey and Lee (2013), and Reimer et al., (2013). All samples were collected by pushing plastic paleomagnetic cylinders into fresh sediment in section faces, which were stored in the cold room at Queens University Belfast prior to submission to the laboratory.

Fig. 1B, View of the G5 mire from the trail up to the Col de la Traversette. Slope in upper segment is the proximal slope of the Younger Dryas moraine complete with a colluvial fan stretching along a ~25 degree slope to the mire.

Fig. 1C, paleomagnetic cylinder used to collect magnetization samples.

3. RESULTS

In addition to the G5 cores and G5A section discussed in Mahaney et al. (2016a, 2016b), three additional sites labeled G5B, G5C and G5D (Fig. 1B) were sectioned and sampled for variations in magnetic susceptibility from near the surface, across the churned-up zone to depth in the section. Samples for magnetic susceptibility were taken across the churned-up beds in each of the three sections to determine if Fe-rich materials could be located at depth and their mineralogy determined. If iron implements, such as knives, swords, belt buckles, equestrian hardware, were lost or discarded, such Fe-rich items might be registered by differences in magnetic susceptibility, so that their relative locations could be determined within the bioturbated or churned-up beds. Such implements might also have been subject to considerable weathering over ~2200 years, resulting in Fe^{+3} being organically-complexed and subject to movement laterally in the pedostratigraphic succession. Previous geochemical analysis (Mahaney et al., 2016a) in the mire did not uncover any vertical movement of Fe. Alternatively, native Fe resident in the peat might contribute to the magnetic signals in recovered samples.

3.1 Sections

The sites (Fig. 1B) are located within meters of one another in proximity to the G5 and G5A sites shown in Fig 3 of Mahaney et al. (2016a). The G5 and 5A sites (2581 m asl) are approximately 0.75 m apart; G5B (2579 m) is 2m ESE of G5 and G5A; G5C (2579 m asl) is 7 m NNW of G5 and G5A; and G5D (2578 m asl) is 9 m S from G5 and G5A.

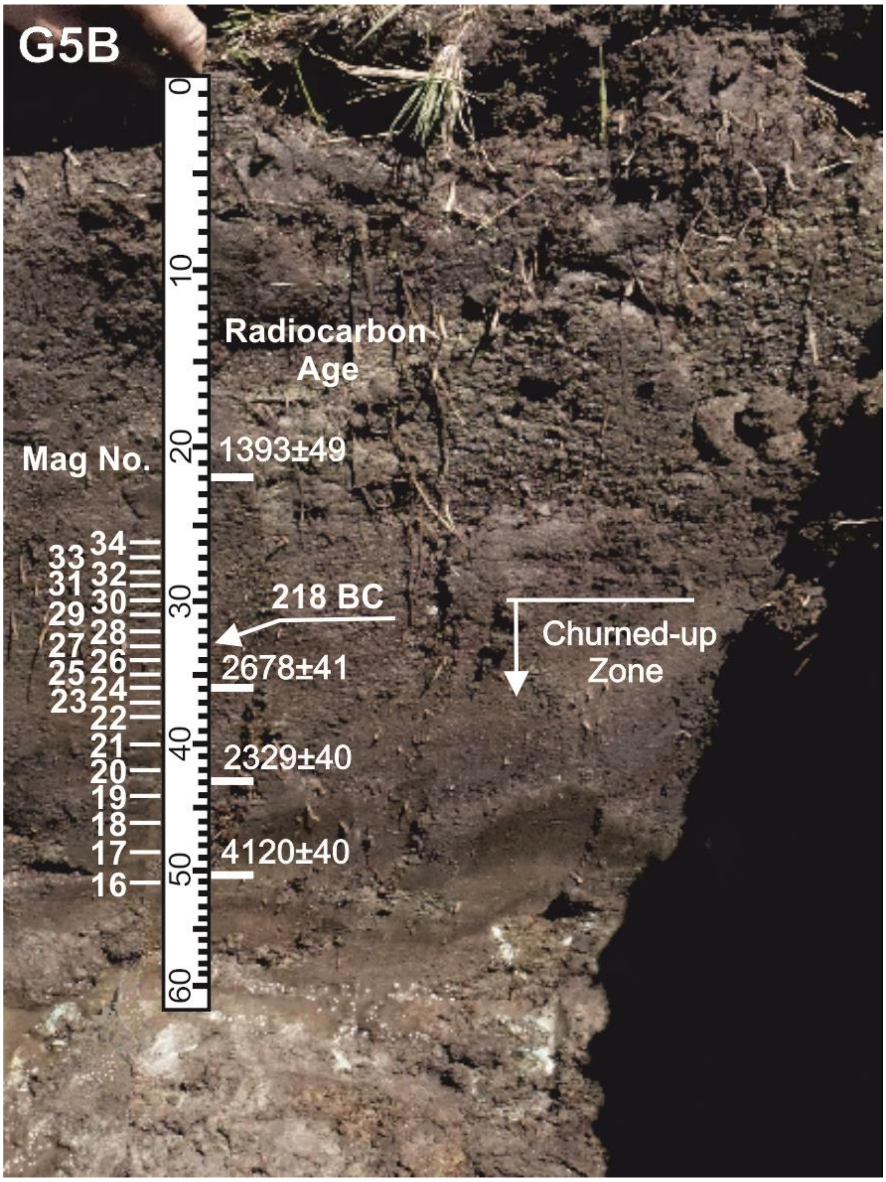

Fig. 2. Excavated G5B section, Guil R., France, elevation 2579 m, 44° 42´ 591"; 07° 03´ 281".

3.2 Age Control

AMS radiocarbon dates for G5B (Fig. 2) are well within the churned-up zone at approximately 33 cm depth, well within the Hemist beds, which are topped off at ~15 cm . The 218 BC bed was determined using Bayesian statistical calculations of the most likely probability of the Hannibal event that occurred between the two dated beds (22cm 1393±49 (UBA-30324) and 35-37 cm 2678±41 (UBA-30321) in Fig. 2. The Hannibal invasion coincides with the 218 BC age in mid-section of the churned-up layer. All dates in Figs. 2-4 are OxCal version 4.2.4 calibrated dates.

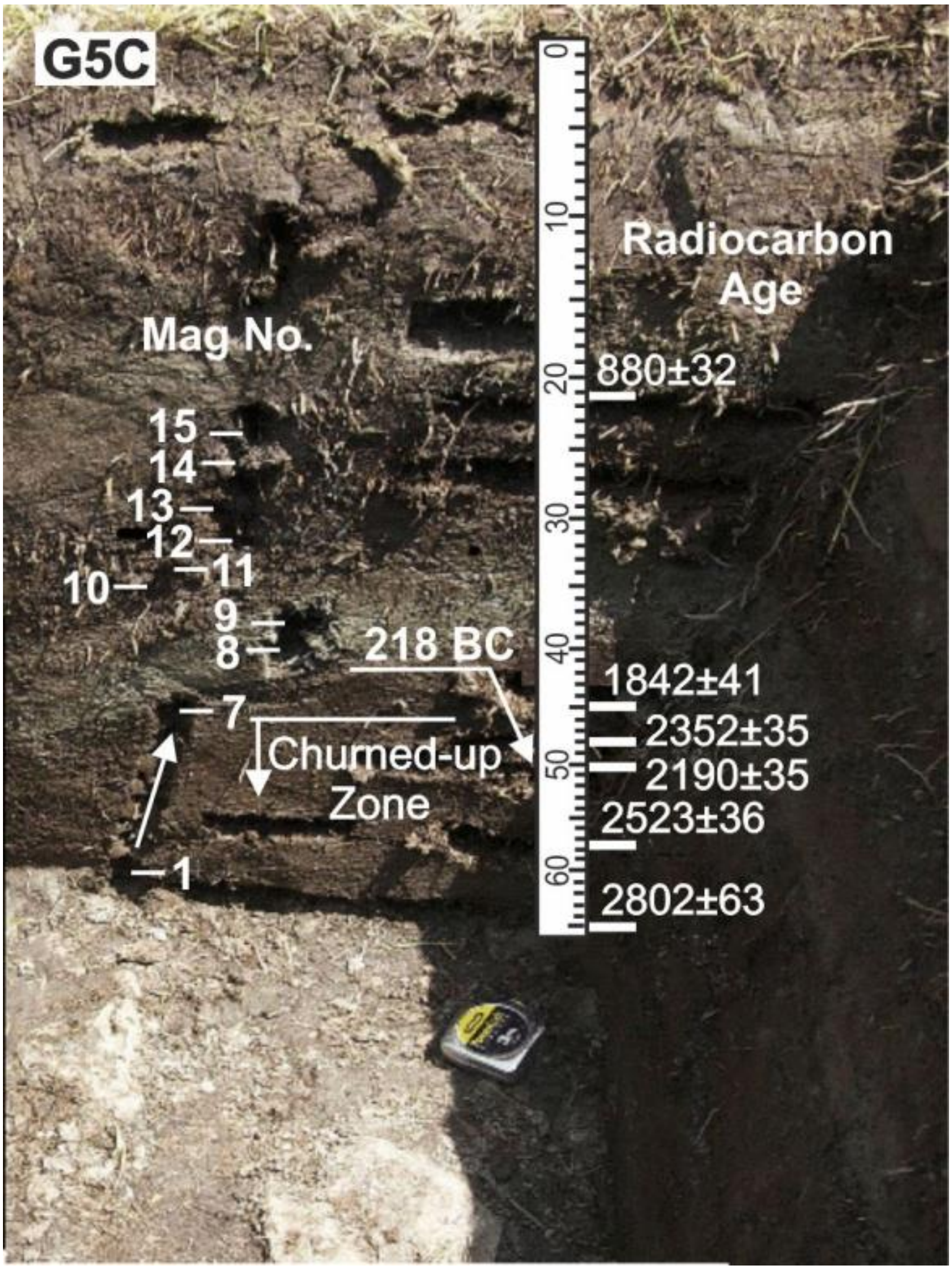

Fig. 3. G5C section, Guil R., elevation 2579 m; 44° 42´ 590″; 07° 03´ 256″.

The 218 BC bed in the G5C section (Fig. 3), at 50 cm depth, is based on Bayesian statistical calculations of registered ages calculated from the three AMS dates targeted. These dates are: 45cm 1842±41 (UBA-30331), 51cm 2190±35 (UBA-30330) and 58cm 2523±36 (UBA-30330).

The 218 BC age in G5D (Fig. 4), at 45 cm depth, is calculated using Bayesian statistics based on two dates which are 35cm 1724±38 (UBA-30318) and 45cm 2329±55 (UBA-30315).

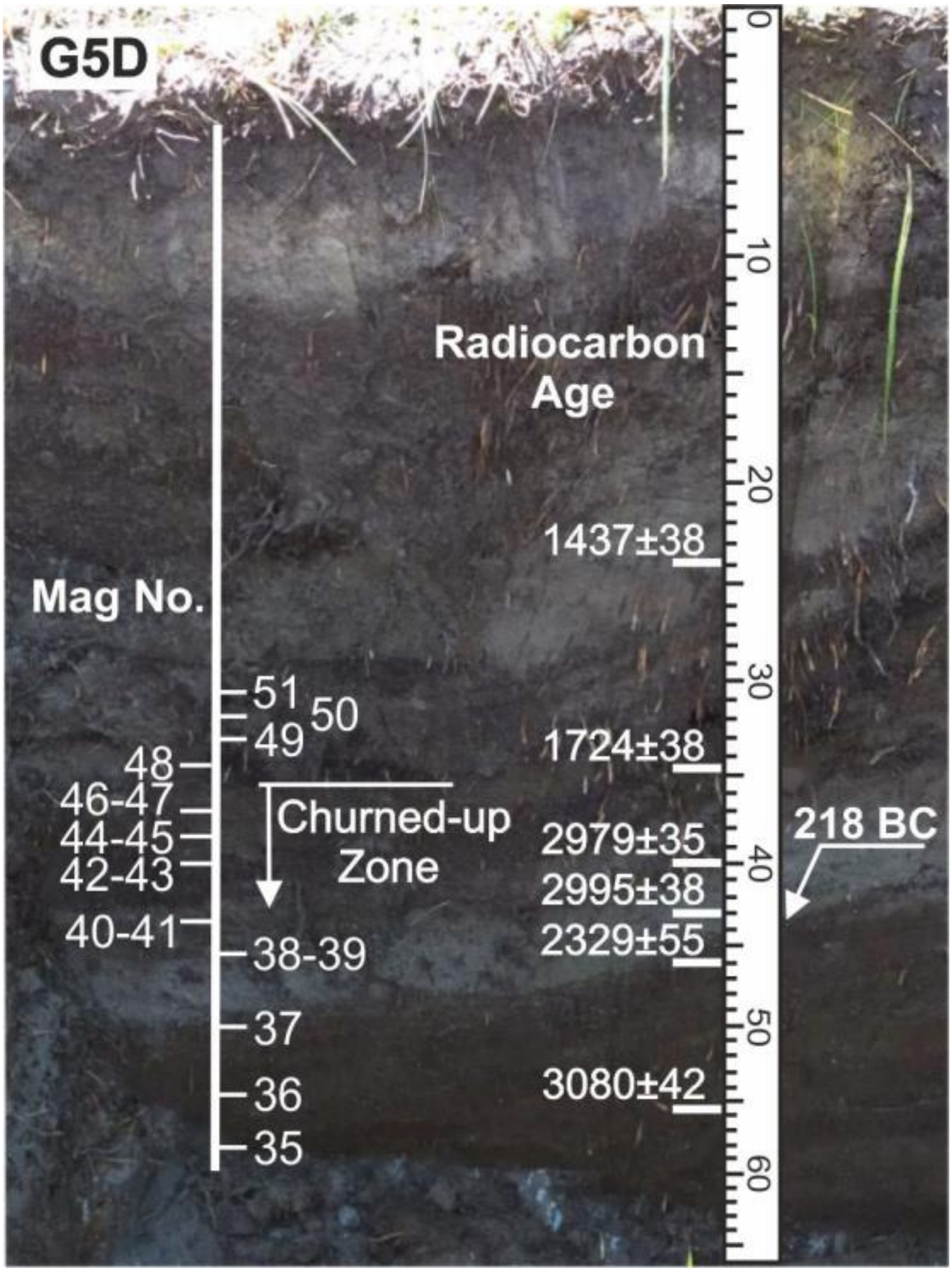

Fig. 4. G5D section, Guil R., elevation 2578 m; 44º 42´ 586″; 07º 03´ 245″.

3.3 *Magnetic Data*

Magnetic susceptibility, defined as the degree of magnetization in an external magnetic field, is the ratio of induced magnetization to the inducing field expressed per unit volume. The volume susceptibility (k) of the Hannibal samples is defined as k=M/H where M is the volume magnetization (these samples) induced in sediment comprising susceptibility k by an applied external field H.

These data measure volume susceptibility, so the resulting units are dimensionless, the measured volumes corrected for collected sediment-filled plastic cylinders (6.58 cc).

To determine if magnetic susceptibility (MS) measurements might reveal the presence of iron from implements in the churned-up beds of all three sections, we collected single strings of samples above, within the disturbed zone, and below in undisturbed beds. The magnetic data (Fig. 5) indicate the MS data is weak overall, even with some negative (diamagnetic) areas within the Histosol, which may mean that whatever magnetite was present within the sediment, including magnetite in any iron weapons that may have been discarded, has converted into Fe-sulphides, an expected result in a reducing environment typical of bogs/mires in general. The magnetic units shown in Fig. 5 are x 10^{-6} MS (SI).

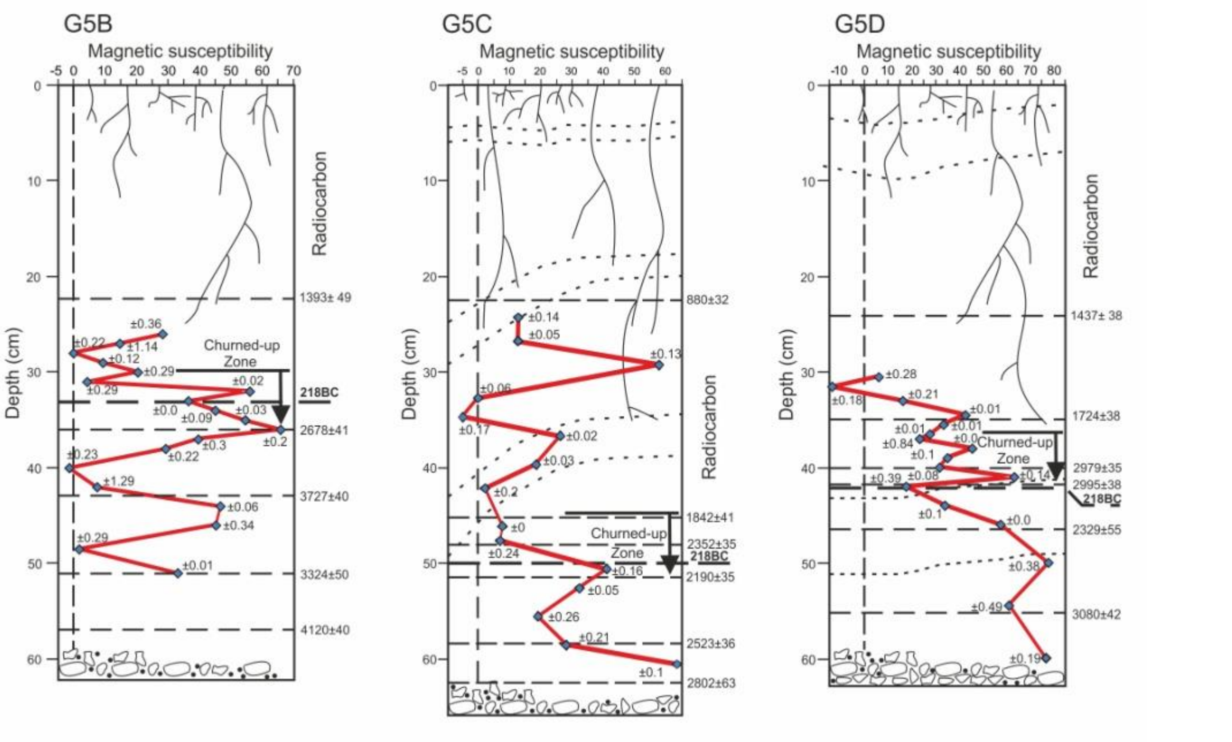

Fig. 5. Magnetic susceptibility data for sites G5B, G5C and G5D, upper Guil catchment, Mt. Viso area.

Despite variations in the amplitude of the churned-up beds across the three sections, the upper surface ranges from 30 cm in G5B, 47 cm in G5C and 37 cm in G5D, highlighting differences in sedimentation rates among the three sections. The mean position of 218 BC (time of the Punic Invasion) is estimated from the AMS ^{14}C dates that straddle the invasion time slot. Overbank sedimentation (small dashed lines) are shown in G5C and G5D. Radiocarbon ages are highlighted by long dashed lines. Considerable variation in MS values down-section in each profile may relate to the presence of iron artifacts or to presence of magnetite minerals from source rock. The MS values are unusually low which may result from reducing conditions that exist in the mire from time to time. The high MS value in G5C at approximately 29 cm depth may well fall within the Medieval Warm Period (MWEP) in the Alps, the age at this depth calculated from younger and older ^{14}C and the calculated sedimentation rate placing the sample at ~1100 cal yr BP**.**

In the G5B section (Fig. 2), out of a total of 19 samples collected, the highest magnetic susceptibility is in the 7 samples crossing the projected 218 BC level. The magnetic susceptibility below the churned-up layer is less than ~45 MS, one sample in negative territory. Above the churned-up bed, all samples fall within values <30 MSA, and a similar trend appears in section G5C (Fig. 3) where 7 samples within the churned-up bed show variability from ~7 to ~40 MS; rising to ~63 MS below the 2523 cal yr BP datum. Given the suspected bioturbation of the sediment it is possible sediment as low as 60 cm could have been disturbed, although the ^{14}C ages are consistent above and below the churned-up bed, inconsistent within the bioturbated zone. The high value (55 MS) at 30 cm depth in G5C, using an inferred age based on a sediment rate of 4.2 mm/yr, could fall within the Medieval Warm Period (MWP) when transhumance activity (Walsh, 2005; Walsh et al., 2007) might have led to discarded tools or weapons. In section G5D (Fig. 4), 9 samples across the churned-up bed show somewhat lower MS values than in G5B and G5C. However the ^{14}C dates within the churned-up bed are age inconsistent as expected within the bioturbated area. With the exception of G5C, the standard errors within the churned-up beds of G5B and G5D are lower compared with samples above and below in both sections.

In all three sections the higher magnetic fluctuations, low as they are, spike within the MAD bed of animal deposition within the time of the Hannibalic invasion of Italia.

While not conclusive evidence of the presence of iron tools, implements related to equestrian materials, weapons, clothing parts, etc., the data do indicate overall that somewhat more iron exists in the churned-up beds than is generally found in overlying and underlying sediment. The data could just as easily reference variations in magnetite that could come from local metabasalt source rock. Overall, the MS values, low as they are, indicate that fluctuating reducing conditions have reduced iron to secondary products, some of which may well have been leached out into the neighboring stream through groundwater at the base of the sections or from leaching of stream water overfilling onto the mire. A test for leaching in the G5 and G5A cores and sections indicates little leaching, which suggests the mire is mostly under reducing conditions, with perhaps aperiodic loss of water and oxidation occurring. Because the churned-up bed contains more organic carbon from feces input and trampled organics and a fluctuating water table it may be that lower pH during times of low water content and oxidizing conditions might weather any iron tools/weapons into Fe^{+3} compounds, whereas with reducing conditions such implements might tend to weather to Fe^{+2}

4. DISCUSSION

The presence of the two-tiered rockfall, frozen ground, and biostratigraphic evidence from the alluvial mire below the Col de la Traversette along the southern route combine to strongly support the hypothesis advanced by Sir Gavin de Beer over half a century ago that Hannibal followed the southern route into Italia. When correlated with other topographic requirements highlighted in the ancient texts of Polybius and Livy, namely, the gorge entrance to the Guil Valley, camping area near the col, view into the Po River plains and the exfiltration regrouping area in the upper Po catchment (outlined in Mahaney, 2008), it is clear de Beer's philological analysis of place names, flooding times of key rivers, and time-motion from New Carthage to southern Gaul and across the Alps, all combine to earmark an area that is worth **exhaustive historical archaeological exploration**. Perhaps the first stage in such an endeavor should start with GPR (Ground Penetrating Radar) analysis of the entire alluvial mire at G5. Such an effort could or should be followed by analysis of other small lakes and mires in the whole of the upper Guil catchment, as well as the rockfall area on the lee side of the range.

Alternative hypotheses for the genesis of the churned-up beds, in addition to trampling by army horses, are overbank sedimentation in times of flood, with discharges sufficient to cut channels to various depths and deposit alluvium or allow frost heave to churn organic sediment upsetting bed horizontality. Additionally, Histosols with variable ratios of organic to mineral matter may with higher organic matter and dung sourced from horses tend to lose bulk density, thus making such beds prone to churning by animals. Such examples of overbank sedimentation with alluvium filling channels of restricted depth are present only in the ~30 cm depth in G5A (Mahaney et al., 2016a, Fig. 3) and in G5C (Fig. 3) and G5D (Fig 4) this paper. Frost churning is unlikely because organic beds act as insulators and if the freezing plane could produce horizon disruption in mineralic paleosols in the area, such effects would have been noted in other studies of local pedons (Mahaney et al., 2016c). Moreover, older paleosols in moraines in the Guil and nearby Po river valleys have not produced bioturbated horizons, not even from the effects of transhumance during the MWP (Mahaney et al., 2013).

The magnetic susceptibility results reported here suggest, but do not prove the residence of iron implements within the churned-up beds of G5B, G5C and G5D. Measured magnetization variability within the churned-up beds may well indicate the presence of iron tools but because MS values are small throughout the sections, such elevated magnetization may only refer to magnetic minerals from the country rock (Tricart et al., 2003). Even if iron tools or weapons are found in the targeted sediment, the likelihood is that they will have been severely weathered, perhaps in some cases, totally altered to Fe-sulfide, possibly recognized only as a 'ghost' mass, similar to other mineralogies like schist and gneiss that are susceptible to rapid weathering, leaving only a mineral mask behind, one that crumbles easily upon contact. Another problem is that during the last ~2000 years, with water movement also evident, there may have likely been both vertical and lateral diffusion of Fe inorganics, even on a minimal basis, resulting from the weathering of iron artifacts.

There is the possibility that variations of Fe levels that have persisted for reasonable periods (i.e. years) may also have affected the distribution of microorganisms in the mire ecology. Metagenome gene sequencing and/or transcriptomics may reveal variations in both Phyla associated with Fe metabolism (e.g. specific Gram negative groups such as *Pseudomonas spp*. and *Geobacter spp),* and known groups of associated genes (e.g. associated with bacteria such as *Geobacter spp.*) that are known to be express specific Fe^{+3} reductases under anerobic conditions, typical for a water-logged environment. However, there is presently scant literature in support of this hypothesis, although our future research will potentially address these possibilities. Such approaches to analysis of the MAD bed would certainly be highly novel – as is the case for our early published work in the emerging field of paleo-microbiology (Mahaney et al., 2016b).

5. CONCLUSIONS

Three sections of alluvial mire sediment in the upper Guil valley of the Western Alps are known to contain physical evidence of mass trampling, presumably by thousands, perhaps tens of thousands of hooves/feet, an event that produced massive churned-up beds within what is otherwise planar bed organic sedimentation. Because the higher than normal organic matter, the gut-derived sterols and the endospore- producing bacteria related to the horse gut are found......change by adding articles where necessary and 'is' becomes 'are' to properly decline the tense. The probability that iron tools or weapons may have been dropped in the mire and lost in the bioturbated sediment is high, which makes this deposit of prime historical archaeological importance.

A preliminary test for iron using magnetic susceptibility is shown to be tentatively positive also for iron variation. Magnetic susceptibility values are generally low, and no doubt, result from high reducing conditions over the life of the peatland, periodically invaded by water from an adjacent waterway and occasionally by the influx of alluvial sediment at least a few times in the ~4 kyr history of peat accumulation. The peat itself is composed of considerable mineral matter, more so than is normally the case, but 5 g wt. samples collected for radiocarbon analysis have produced dates with very tight standard deviations, so that normally one standard deviation is less than 40 yrs, <0.02 %, which means the age is largely unaffected by water or organic/inorganic sediment throughput. The marginally increased magnetic susceptibility measurements within the churned-up beds indicate the mire should be subjected to metal detection and ground penetrating radar imagery to determine what, if any, iron implements/artifacts might be present. If such tools and implements are found it is highly likely they relate to the passage of the Punic Army in 218 BC, because the anomalous bioturbation event is radiocarbon dated to precisely the time of the invasion.

ACKNOWLEDGEMENTS

This research was funded by Quaternary Surveys, Toronto.

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