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A multidisciplinary overview of the Lower Miño River terrace system (NW Iberian Peninsula): a response to comments by Viveen et al. (2020)

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Abstract

Viveen et al., (2020) raise several issues concerning the chronostratigraphic interpretations in our recent paper on the fluvial and archaeological deposits of Lower Miño River (Méndez-Quintas et al., 2020). Here we respond to these criticisms, reinforcing the key findings of our study and questioning the validity of their arguments. We find that the concerns of Viveen et al. (2020) are based on a series of poorly founded assumptions and generalisations, invalid comparisons, and inappropriate data analyses.

Keywords

Fluvial terrace; Miño River basin; Pleistocene; Geomorphology; Dating.

In their recent comment, Viveen et al., (2020) question some of the methods and results presented in our geomorphological, geochronological and archaeological examination of the Lower Miño River terrace sequence (Northwest Iberian Peninsula) (Méndez-Quintas et al., 2020). In particular, they take issue with the need to re-map the fluvial outcrops of the region, the focus of our study on a single river bank (Spanish side), and the correlation of river terrace levels across different parts of the basin. Here we respond to the main criticisms of Viveen et al., (2020), and in turn question the validity of their arguments.

Viveen et al, (2020) query our decision to undertake a new cartographic assessment of fluvial outcrops in the lower Miño River basin given their previous research in the region (Viveen et al., 2012a; 2012b; 2013a; 2013b; 2014). This decision was based on the need to have more refined contextual assessments of archaeological deposits in the region, and to derive more comprehensive maps that incorporated morphological interpretations of aerial photography, Digital Elevation Models (DEM) and our extensive fieldwork reconnaissance. We did not feel that the existing cartography, which was published in the most detail in Viveen et al., (2013), had adequate resolution and coverage for the needs of our research (**Fig. 1**). Moreover, after undertaking our own reconnaissance work, we did not agree with some of the existing morphological interpretations or with the mapped limits for some of the fluvial outcrops in the region. Indeed, Viveen et al. (2012a) acknowledge that there is need for further refinement of the Lower Miño River cartography, stating that "*the Miño record has received little attention*", "*The number of terrace levels and their spacing is still a topic of discussion*" and "*A detailed regional framework for the terraces is still lacking and no consensus exists on the number of terrace levels*." We would agree with these statements and see our contribution as an important part of an ongoing research dialogue within the basin.

The absence of the Portuguese side of the Miño River (south side of the basin) in our geomorphological assessments reflects two practical constraints. First, the basic cartographic information available for the Portuguese side of the river (DEM, aerial photography and other layers of information) is much less complete than for the Spanish side. As shown in **Fig. 2**, the coverage of the DEM datasets, which we obtained from the Spanish National Geographic Institute (IGN), only partially covers the Portuguese bank of the river. According to the methodological sections of the various publications by Viveen et al., (2012a; 2012b; 2013a; 2013b; 2014), these DEMs form the basis of their cartographic interpretations of fluvial outcrops; this would explain why there are incomplete and unmapped areas in their cartographies (**Fig. 2**). The second reason for not including the Portuguese side of the basin in our article is that this region is the focus of a dedicated research project that is currently underway (*Miño/Minho, Os primeiros inhabitants do Baixo Minho. Estudo das occupações pleistocénicas da região*). This project involves detailed examination of the fluvial formations on the Portuguese side of the Miño river, as well as the associated Palaeolithic occupation record (Cunha Ribeiro et al., 2017). This project was not sufficiently advanced at the time of our publication, and we did not consider it appropriate to include datasets from the Portuguese side of the basin in our synthesis paper before they had been published in detail as part of their own specific studies.

These two practical constraints do not mean that we consider the Portuguese side of the river unimportant. Rather, our view was that the available datasets for the Portuguese side of the basin did not meet the necessary standards to ensure comparable or complete assessments with the Spanish side of the basin. Our approach was designed to ensure that the conclusions reached in our article were supported by clear and sufficient data, and were firmly established for the study area under consideration. We prefer to examine the Portuguese records as part of dedicated studies using appropriate and complete datasets, as they become available. That said, our ongoing research on the Portuguese side of the river suggests that the overall conclusions of Méndez-Quintas et al. (2020) are unlikely to be significantly altered by inclusion of the Portuguese datasets in future publications.

The main criticism by Viveen et al. (2020) focuses on the correlation of river terrace levels throughout the basin. In our work, we establish the existence of nine terraces based on extensive landform classification and cross-sectional surveying, with each terrace being defined relative to the current river level as follows: +4-7 m (T1), +13-17 m (T2), +21-29 m (T3), +30 -39 m (T4), +45-51 m (T5), +53-61 m (T6), +65-77 m (T7), +78-89 m (T8) and +91-108 m (T9) (Méndez-Quintas et al., 2020). In Viveen et al. (2020), as well as in their related publications (Viveen et al., 2013a; 2013b; 2014), correlation of the terrace deposits is not defined by elevation relative to current river level but instead is based primarily on the state of alteration of quartzite clasts within the sedimentary deposits, with supporting evidence coming from observations of diminishing elevations for the highest terrace in a downstream direction, and *minimum* (essentially non-finite) age estimates determined from ^{10}Be cosmic ray exposure (CRE) and luminescence dating (see discussions later). On the basis of quartzite weathering alteration trends, Viveen et al. (2013a, 2020) suggest that the Miño terraces can be correlated throughout the basin by assuming a seemingly universal inclination gradient of 1 m / km, which is summarised in the model shown in Fig. 9 of Viveen et al., (2013a).

Before examining the potential issues of basin-wide geomorphic interpretations founded on quartzite weathering conditions, it is worth clarifying that the approach used by Méndez-Quintas et al. (2020) to correlate river terraces according to relative elevation above river level does not simply equate to "*horizontal correlations (that are) not taking into account a paleofluvial gradient*", as stated by Viveen et al. (2020). We have correlated terraces according to multi-faceted base level reconstructions that are most relevant for each of the various parts of the basin under consideration. Examination of our reconstructed terrace levels for the entire Lower Miño River basin (i.e., the last 85 km of the river rather than the lowermost 55 km selected by Viveen et al., 2020 in their Fig. 1) clearly shows this to be the case (see Fig. 10 of Méndez-Quintas et al., 2020), and that our correlative approach does not equate to horizontal terrace mapping. Fig. 10 of Méndez-Quintas et al. (2020) also demonstrates that a one-size-fits-all approach to terrace correlation based on an inferred inclination gradient of 1 m / km is over-simplistic when considering the Lower Miño River basin as a whole. Furthermore, comparison of Fig. 1 from Viveen et al. (2020) and Fig. 10 from Méndez-Quintas et al. (2020) appears to highlight significant differences in terrace surface mapping resolution, which could partly explain differences in terrace correlations (**Fig. 3**). In particular, Méndez-Quintas et al. (2020) undertook 72 terrace surface measurements over the lower 40 km of the basin and 107 measurements over the lowermost 55 km of the basin (all on the northern side of the basin). In contrast, Fig. 1 of Viveen et al. (2020) undertook 46 terrace surface measurements over the lower 40 km of the basin and 67 measurements over the lowermost 55 km of the basin – i.e., 35-40% fewer measurements, in spite of considering both sides of the basin. It is also worth noting from Fig. 10 of Méndez-Quintas et al. (2020) that the relative elevation of the highest river terrace (another criteria used to support Viveen et al's (2020) oblique angle terrace correlation model) exhibits a non-monotonic relationship throughout the basin rather than a uniform diminishing downstream elevation (**Fig. 3**). This observation reinforces the complex relationships of terrace gradients over the full extent of the basin, and is entirely in keeping with our correlative approach based on spatially variable relative elevation ranges.

Viveen et al.'s (2013a, 2020) proposal of a chronosequence based on the degree of alteration of quartzite clasts within the terrace deposits, and therefore edaphic development stages, is interesting. Viveen et al. (2013a) fail to acknowledge that differences in the alteration of quartzite clasts between terrace levels is not a new proposal for the Miño basin. K. W. Butzer observed variations in rock type and its state of conservation between terraces in his article on the geomorphology and stratigraphy of the Paleolithic site of Gándaras de Budiño (Butzer, 1967: 93-94). Later, Pérez-Alberti et al., (2013) also developed a similar hypothesis for this basin, though further upstream from our work area. Importantly, however, this method of terrace correlation is only valid if due consideration is given to the assumptions, limitations and implicit generalisations underpinning quartzite alteration datasets. From the data published in Viveen et al., (2013a), and adopted in successive studies (Viveen et al., 2013b; 2014), this does not seem to be so, and we observe several methodological and interpretive problems that invalidate their conclusions, as detailed below:

1. The assumption that all quartzites within the fluvial deposits are mineralogically homogeneous. According to Viveen et al., (2013a), within the terrace deposits of the study area, "*all quartzite clasts have a more or less similar initial mineralogical composition […] The quartzite pebbles in the lower Miño terraces originate from the same source, namely the Bierzo basin and surroundings (Viveen et al., 2012b). In this area, river captures by the Miño−Sil rivers have not been reported for the middle Pleistocene (Garcia-de Celis, 1997). For this reason we argue that the type of quartzite in the lower Miño terraces has not significantly varied through time*". Demonstrating the accuracy of this assertion is fundamental to validating the correlative terrace model defended by Viveen et al., (2013a) since any variability in the mineralogical composition and geological origin of the quartzite facies will directly affect the density of the rock and, therefore, its propensity for chemical alteration. The fluvial catchment of the Miño-Sil river erodes several geological settings containing quartzites and other sedimentary and metamorphic rocks that can be confused with each other in the absence of specific petrological controls. Thus, within the basin there are extensive primary outcrops of different geological ages, as well as Cenozoic sediments (dated to both the Tertiary and Quaternary), with quartzites in different states of mechanical and chemical alteration (**Fig. 4**). Even within the primary quartzite outcrops of the Miño-Sil basin, we find extensive geological and chronological variability. A prime example is the “Serie de los Cabos”, which contains “Armorican” quartzite levels that are up to 4500 m thick (Pérez-Estaún and Bea, 2004). The assumption that the clasts analysed by Viveen et al., (2013a) are all quartzites, or, failing that, all have similar petrological features and, therefore, similar initial densities, cannot be justified with the data provided. As such, the model put forward by the authors remains invalid.

2. Inaccuracies in the geographical position and heights of the sampled points. Viveen et al. (2013a) explain that the areas analysed for their quartzite alteration assessments span Chan de Vide (As Neves, Pontevedra), Caldelas de Tui (Tui, Pontevedra), Vila Meã (Vila Nova de Cerveira-Valença, Portugal) and O Rosal (O Rosal, Pontevedra). Geomorphological sections and maps are presented, as well as some sedimentary information (Viveen et al., 2013a: Fig. 4-5 and Table 2). Incomprehensibly, quartzite density data were not collected from the Caldelas de Tui locality and were instead substituted by those from another unspecified sector at Monção (Portugal), which does not have adequate geomorphological characterisation in the article (Viveen et al., 2013a: Table 3). The first problem we observe with this analysis is that when projecting the sampled points onto cartography (using the data from Table 3 of Viveen et al., 2013a), the position of several points is anomalous and/or contradictory to what is described by the authors (**Fig. 5**). Likewise, we observe significant differences in terrace height values for the various sampled points calculated by us and those provided by Viveen et al. (**Table 1**). These inaccuracies, particularly those related to the height of the sampled points, have a direct impact on the interpretation of the data related to quartzite density variations and, therefore, the very reliability of the correlations established in Viveen et al. (2013a) (and assumed in subsequent papers; Viveen et al., 2013b; 2014). After reading the bibliography of the aforementioned studies, we observe that there is an underlying and unclear use of absolute and relative heights to the current river level, which gives rise to notable uncertainties in their evaluations.

3. Methodological problems: Invalid statistical foundations, insufficient stratigraphic information, inadequate consideration of the evolution of each sequence. Apart from the aforementioned discrepancies in the positioning and heights of sampled points, we observe several other significant methodological problems with the quartzite alteration assessments of Viveen et al. (2013a). First, thorough characterisation and description of the sampled sections is lacking; there are no detailed stratigraphic descriptions, logs and/or photographs that would otherwise allow adequate understanding of the type of sedimentary beds that have been sampled. This is particularly important when taking into account that the fluvial deposits are commonly capped by other deposits that have lateral origins (e.g., alluvial fans, colluvium deposits). The deposition of these lateral sediments is, therefore, subsequent to the formation of the terraces and usually incorporates materials from other deposits, including higher terraces (Méndez-Quintas et al., 2020). Assuming that the sampled deposits are derived exclusively from primary fluvial layers, we observe a more significant problem: the absence of quartzite density variation analyses throughout each of the sampled sections. This consideration is particularly important because the exclusion of density variation analysis throughout each individual sample section means it is difficult to evaluate the representativeness of the average values and standard deviations derived for different terrace levels (see Table 3 of Viveen et al., 2013a). In addition, it is noteworthy that a very low number of terrace localities have been analysed (16, discounting the floodplain sample) for the size of the study area and the number of identified terraces. Another important methodological problem relates to the insufficient statistical significance of the clast density relationships for the different terrace levels. For instance, there is no statistically significant difference between the clast density data associated with levels T2, T3, T4 and T5. The Chi-square test (X^2) results for these various samples are as follows: T1-T2 $X^2 = 0.004$, $p = 0.94$; T2-T3 $X^2 = 0.02$, $p = 0.98$; T3-T4 $X^2 = 0.002$, $p = 0.99$; T4-T5: $X^2 = 0.01$, $p = 0.99$. In all cases, the density values are statistically indistinguishable. If we apply this same statistical test to terraces that have more disparate chronologies, the outcomes are again similar, with null statistical differences: T2-T4: $X^2 = 0.02$, $p = 0.98$; T2-T5: $X^2= 0.02$, $p = 0.98$; T2-T5: $X^2 = 0.03$, $p = 0.98$. The application of other non-parametric statistical tests, such as the One-way Anova ($F = 1.562$, $p = 0.276$) or the Kruskal-Wallis ($H = 5.55$, $p =$

0.133) test, yield identical results; that is, there are no statistically significant differences in the density (alteration) values observed for the points sampled by Viveen et al., (2013a).

The various arguments outlined in the preceding paragraphs affirm that the terrace correlation model proposed by Viveen et al. (2013a), which forms the main argument of the comment by Viveen et al., (2020), is not based on solid evidence. The non-trivial problems associated with their methodological approach, data interpretation and cartographic evaluations, prevent us from accepting their terrace correlation model, especially after taking into account the results of our own investigations in the study area.

Viveen et al. (2020) invoke several ancillary arguments about the chronology, sedimentary characteristics and tectonic evolution of the basin to further criticise our terrace correlations. We feel that these arguments are founded on biased interpretations of available data, and that our views have been misinterpreted to support an alternative standpoint. A case in point is the inappropriate comparison of the numerical chronologies for the sequences containing the Palaeolithic site of Porto Maior (As Neves) (Méndez-Quintas et al., 2018; Demuro et al., 2020a, 2020b) and Furna (Valença do Minho, Portugal) (Viveen et al., 2012a). Viveen et al. (2020) affirm that the fluvial sequence of the Porto Maior deposit, which has a relative elevation of +34 m and is associated with the T4 terrace (+30-39 m) in our scheme (Méndez-Quintas et al., 2018; 2020), correlates with the T2 terrace from their scheme and that the similarity of available numerical ages for both sites vindicates their own terrace correlation model. Specifically, Viveen et al. (2020) claim that the ages obtained for the Furna T2 terrace, which are based exclusively on ^{10}Be dating because of signal saturation problems with the associated luminescence chronologies, are 196 ± 5.9 ka and 187 ± 5.8 ka, and that these are statistically indistinguishable from the TT-OSL, pIR-IR and ESR chronologies obtained for the PM4 level at Porto Maior, whose average deposition age is 210.7 ± 24.7 ka (Demuro et al., 2020a; 2020b). Unfortunately, as previously acknowledged by the authors themselves, the cosmogenic ages of Viveen et al (2012a) are not without their interpretive complications, and from a strictly methodological perspective their CRE rejuvenation approach provides minimum rather than finite ^{10}Be age estimates for the Furna T2 terrace. Indeed, Fig 11. of Viveen et al. (2012a) states: *"The rejuvenation approach ages are strictly minimum ages. Max. age error bar for Furna, Furna Top and VM terrace not given because these maximum ages are unrealistic and obstruct the clarity of the drawing*". Viveen et al. (2020) seemingly chose to ignore the methodological caveats they previously placed on the Furna CRE ages, or else they are unaware that it is statistically invalid to compare the finite ages we obtained at PM with the minimum ages they obtained for the Furna terrace; this is akin to comparing chronological apples and oranges. Irrespective, the available CRE ages do not support the proposed chronostratigraphic interpretations of Viveen et al. (2020) due to methodological limitations, as already outlined in Méndez-Quintas et al. (2020).

Methodological issues aside, it is also clear that the Furna CRE ages and the Porto Maior PM4 ages are not stratigraphically comparable from the point of view of their geodynamic formation processes. At least a part of the sequence dated at Furna represents fluvial terrace level T2 (+13-17 m). On the other hand, as indicated in all of our published works on the Porto Maior sequence, the PM4 and PM5 levels are deposited atop the T4 terrace fluvial sequence (i.e., the T4 terrace sequence comprises levels PM1-3). This is evidenced by the erosive and chronological discordance observed between level PM3 and level PM4 (Méndez-Quintas et al., 2018; Demuro et al., 2020a; Méndez-Quintas et al., 2020). As such, Viveen et al. (2020) should have chosen to establish their correlation with the PM1-3 fluvial terrace levels of the Porto Maior sequence, which are dated to between 312.6 ± 32.6 and the 258.3 ± 12.1 ka (Demuro et al., 2020a; 2020b; Méndez-Quintas et al., 2020). When considering these chronostratigraphic data (again, putting methodological considerations aside), it is clear that the two fluvial terrace levels at Furna and Porto Maior do not correspond to contemporaneous geodynamic events, as is already apparent from their different geomorphological positions. These data underscore the inconsistency of the correlation model proposed by Viveen et al., (2013a), which remains the foundation of the authors later interpretations on the Lower Miño River terrace system development.

Elsewhere in their critique, Viveen et al. (2020) claim that our terrace correlations are founded on the presence of "*fine-grained sediments with a clay illuviation horizon*" and that, contrary to our claims, they "*have encountered fine-grained deposits in, or on top of, the gravels, only in a few occasions.*" To clarify, Méndez-Quintas et al. (2020) did not claim that these fine-grained sediment were used for regional correlations or that they are ubiquitous in the basin. We state that these deposits are widespread for the T4 terrace, which we maintain based on our extensive surveying of the basin. Moreover, we are not the first to make such claims; the identification of edaphic processes in the form of horizons B and orange colouration for the middle and upper terraces was one of the most significant findings of Butzer's (1967) seminal work. For the purpose of adopting shorthand terminology in our study, and given our interest in the archaeological assemblages associated with these T4 deposits, we informally used the term "Porto Maior Formation", taking care to use parentheses to distinguish the intended restricted scope of this terminology. This approach does not equate to proposing a formal geological Formation for the region, which would have certainly been beyond the scope of our paper.

Finally, Viveen et al. (2020) also critique our interpretations of neotectonic influences in the Lower Miño River basin, but in doing so appear to have selectively quoted our discussions on this subject. Clearly, we are aware of the broader geological setting of the Iberian Peninsula, and the general role that tectonics plays in long-term base-level change across the region, as stated multiple times in Méndez-Quintas et al. (2020). However, a key consideration is the relative role played by tectonic forcing at different geographic scales, both during and after the development of the various terrace levels, and our chronostratigraphic data suggest this relationship is not necessarily as straight-forward or widespread as has been previously assumed. We dedicated significant discussion to this subject in Méndez-Quintas et al. (2020), and do not feel that the latest comments of Viveen et al. (2020) offer any specific advancement to understanding the neotectonic history of the basin.

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FIGURE AND TABLE CAPTIONS

Fig. 1. Example of the cartography of Viveen et al. (2013b) (a) and Méndez-Quintas et al. (2020) (b) for the central section of the studied area.

Fig. 2. The cartography of Viveen et al., (2013b) showing the coverage of the 5 m-resolution DEM (IGN) across the study area (grey shaded area). Areas not mapped due to the absence of information layers are indicated by the black boxes.

Fig. 3. Correlation models of fluvial terraces according to Viveen et al., (2013a) (a) and Méndez-Quintas et al., (2020) (b), where it is possible to observe some difference in the extension of the basin considered and in the number of points sampled.

Fig. 4. Main outcrops of rock formations containing quartzites within the limits of the Miño-Sil River Basin. Data based on the *Mapa Geológico de la Península Ibérica, Baleares y Canarias a escala 1:1.000.000* (Rodriguez-Fernández and Oliveira, 2015).

Fig. 5. Map with the location of the sampled points according to the information provided by Viveen et al., (2013a). Several of the sample points are fully displaced from their original position, as indicated by red arrows.

Table 1. Data extracted from Table 3 of Viveen et al., (2013a) compared with the absolute height calculated from the 5 m DEM (IGN) (Méndez-Quintas et al., 2020). The difference in height with respect to that reported in Viveen et al., (2013a) is shown with * when it exceeds ±5 m. The final column shows the correlation with the terrace model proposed by Méndez-Quintas et al., (2020).

Viveen et al. (2020) data								Méndez-Quintas et al. (2020) data		
Transect	Terrace (m)	Terrace level	Coordinates	Sampled depth	n	Density (g cm−3)	σ2	Absolute height (m)	Difference	Terrace level
CDV	13	Floodplain	550551 E, 4658563 N	0	40	2.42	0.07	36,1	-23,1*	Floodplain
CDV	35	T1	547157 E, 4658686 N	3	87	2.42	0.09	51,1	-16,1*	?
CDV	50	T2	550861 E, 4658932 N	2.5	73	2.38	0.11	55,2	-5,2*	T5
CDV	60	T3	550901 E, 4659197 N	2.5	107	2.25	0.13	66	-6*	T7
CDV	71	T4	550732 E, 4659520 N	3	92	2.22	0.13	81	-10*	T8
Monção	42	T2	541193 E, 4658599 N	3	101	2.24	0.12	1	41*	T1
Monção	49	T3	542122 E, 4658411 N	3	84	2.23	0.11	32,8	16,2*	T4
Monção	63	T4	544315 E, 4658378 N	2.5	82	2.18	0.14	37	26*	T4
Monção	80	T5	544371 E, 4657852 N	3	91	2.18	0.12	48	32*	T5
Vila Meã	13	T1	526500 E, 4649280 N	3	96	2.33	0.11	25	-12*	T2
Vila Meã	31	T3	526030 E, 4647014 N	3	89	2.26	0.12	12	19*	T3
Vila Meã	41	T4	526303 E, 4646580 N	3	105	2.23	0.12	23	18*	T4
Vila Meã	53	T5a	528643 E, 4647919 N	3	107	2.13	0.11	39,7	13,3*	T5
Vila Meã	64	T2	531227 E, 4649965 N	3	102	2.09	0.11	63	1	T6
O Rosal	33	T3	513178 E, 4641262 N	3	116	2.19	0.13	34	-1	T4
O Rosal	40	T4	512905 E, 4642945 N	3	110	2.18	0.11	37	3	T4
O Rosal	50	T5	513692 E, 4643220 N	3	71	2.04	0.11	39	11*	T5

Table 1

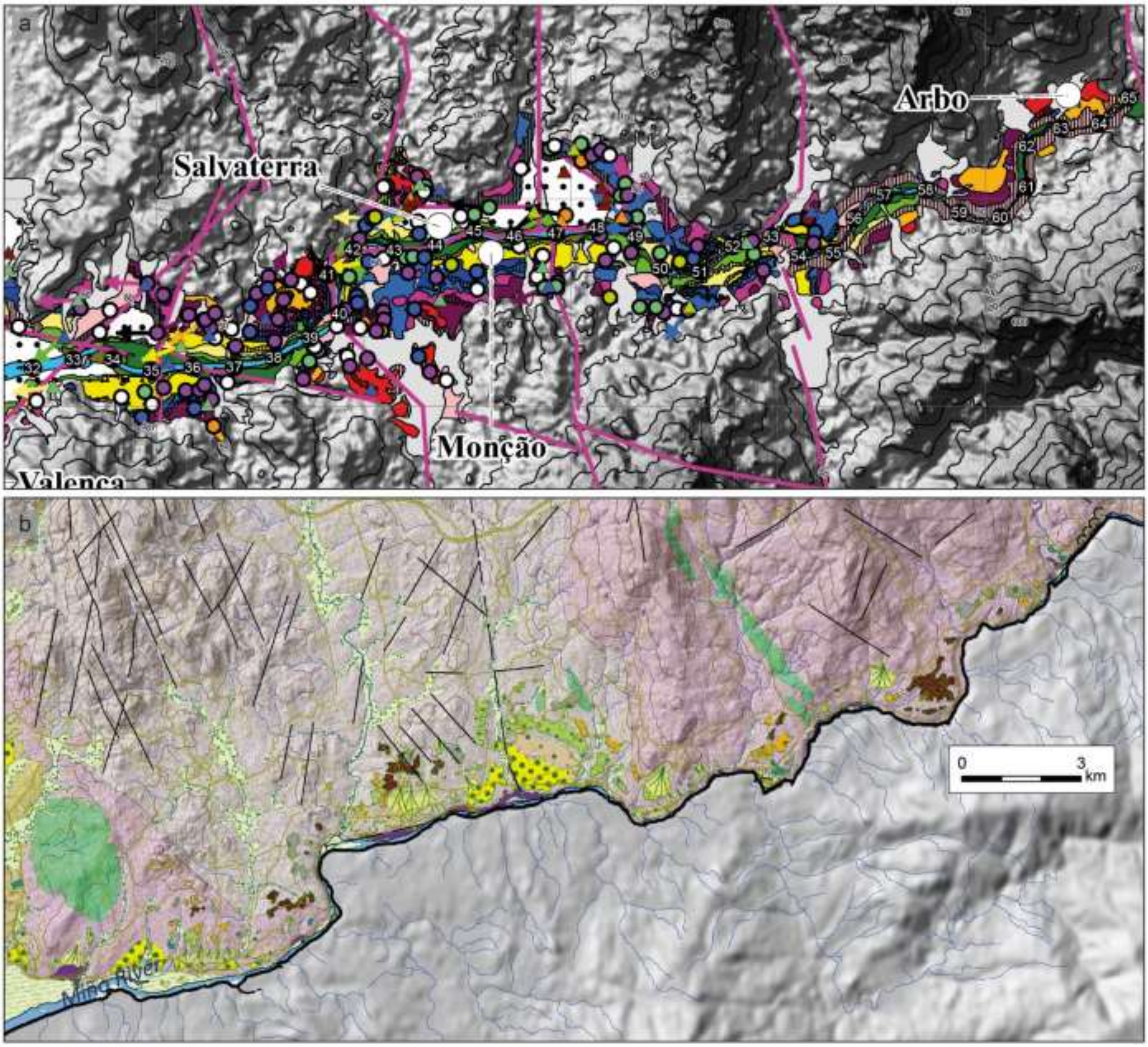
a
Salvaterra
Arbo
Monção
Valença
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
b
Minho River
0
3
km

Fig. 1.

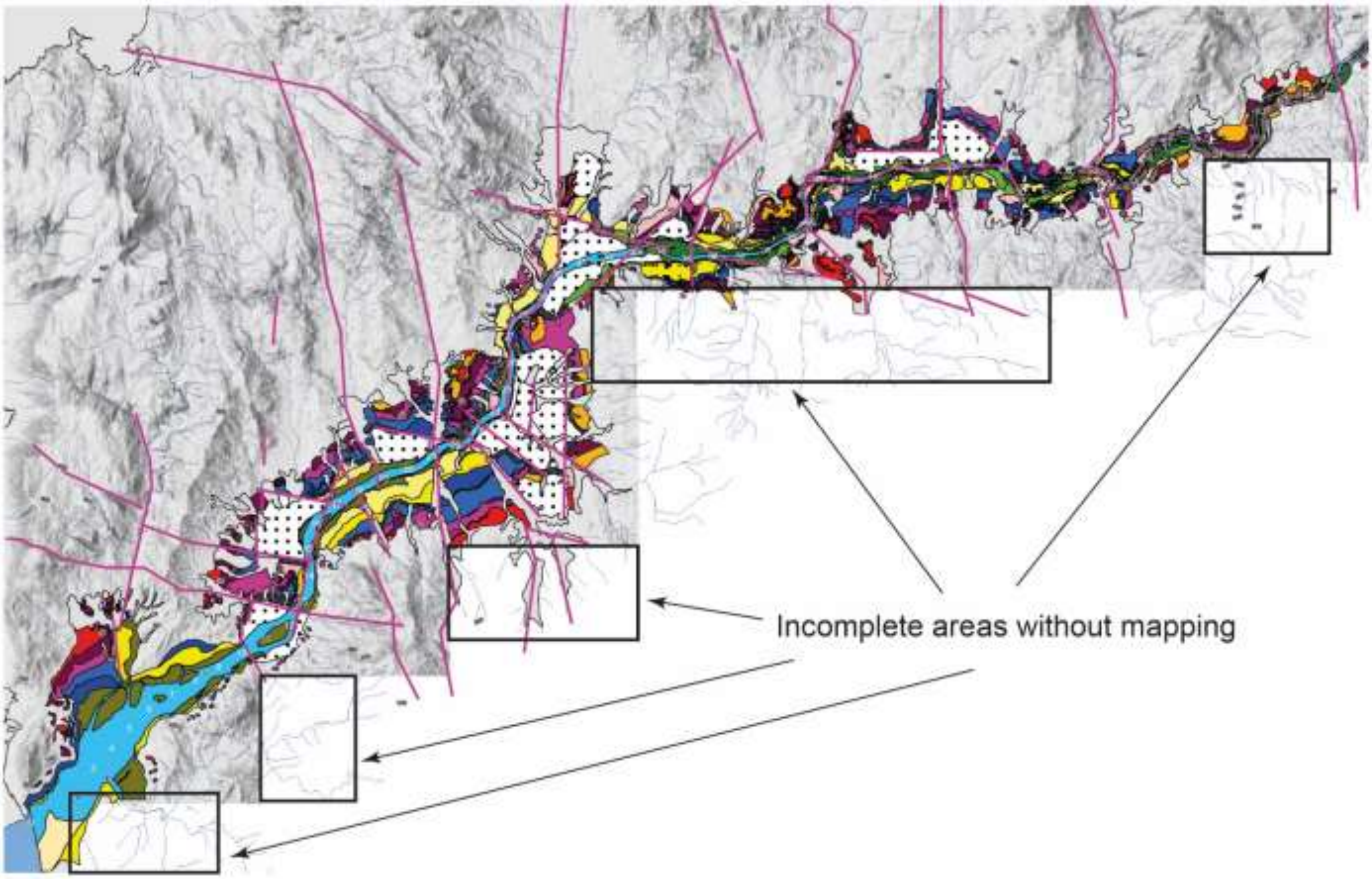

Fig. 2

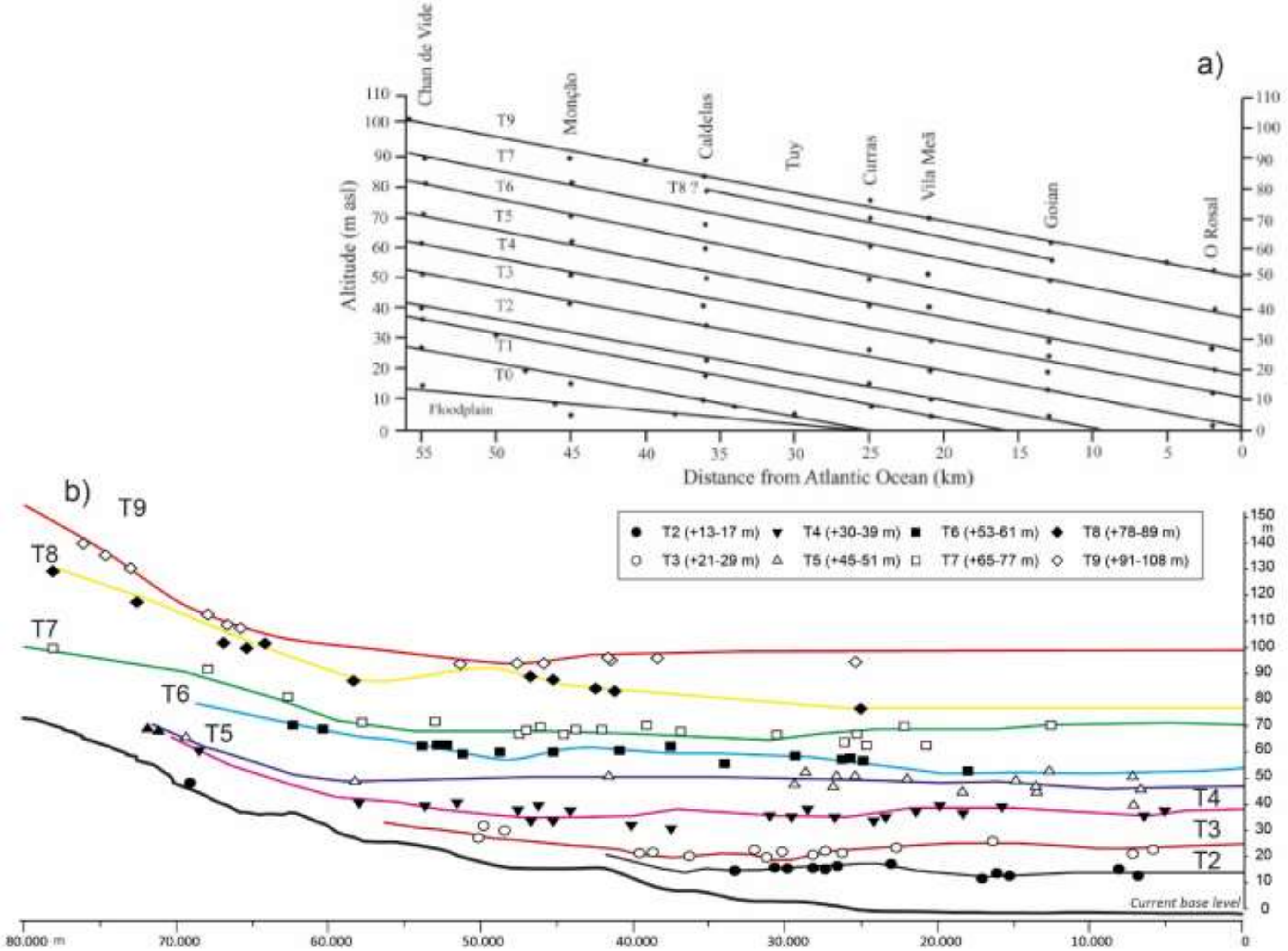
a)
Chan de Vide
Monção
Caldelas
Tuy
Curras
Vila Meã
Goian
O Rosal
T9
T7
T6
T5
T4
T3
T2
T1
T0
T8 ?
Floodplain
Altitude (m asl)
Distance from Atlantic Ocean (km)
0
10
20
30
40
50
60
70
80
90
100
110
55
50
45
40
35
30
25
20
15
10
5
0
b)
T9
T8
T7
T6
T5
T4
T3
T2
● T2 (+13-17 m)
○ T3 (+21-29 m)
▼ T4 (+30-39 m)
△ T5 (+45-51 m)
■ T6 (+53-61 m)
□ T7 (+65-77 m)
◆ T8 (+78-89 m)
◇ T9 (+91-108 m)
Current base level
m
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
80.000 m
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0

Fig. 3

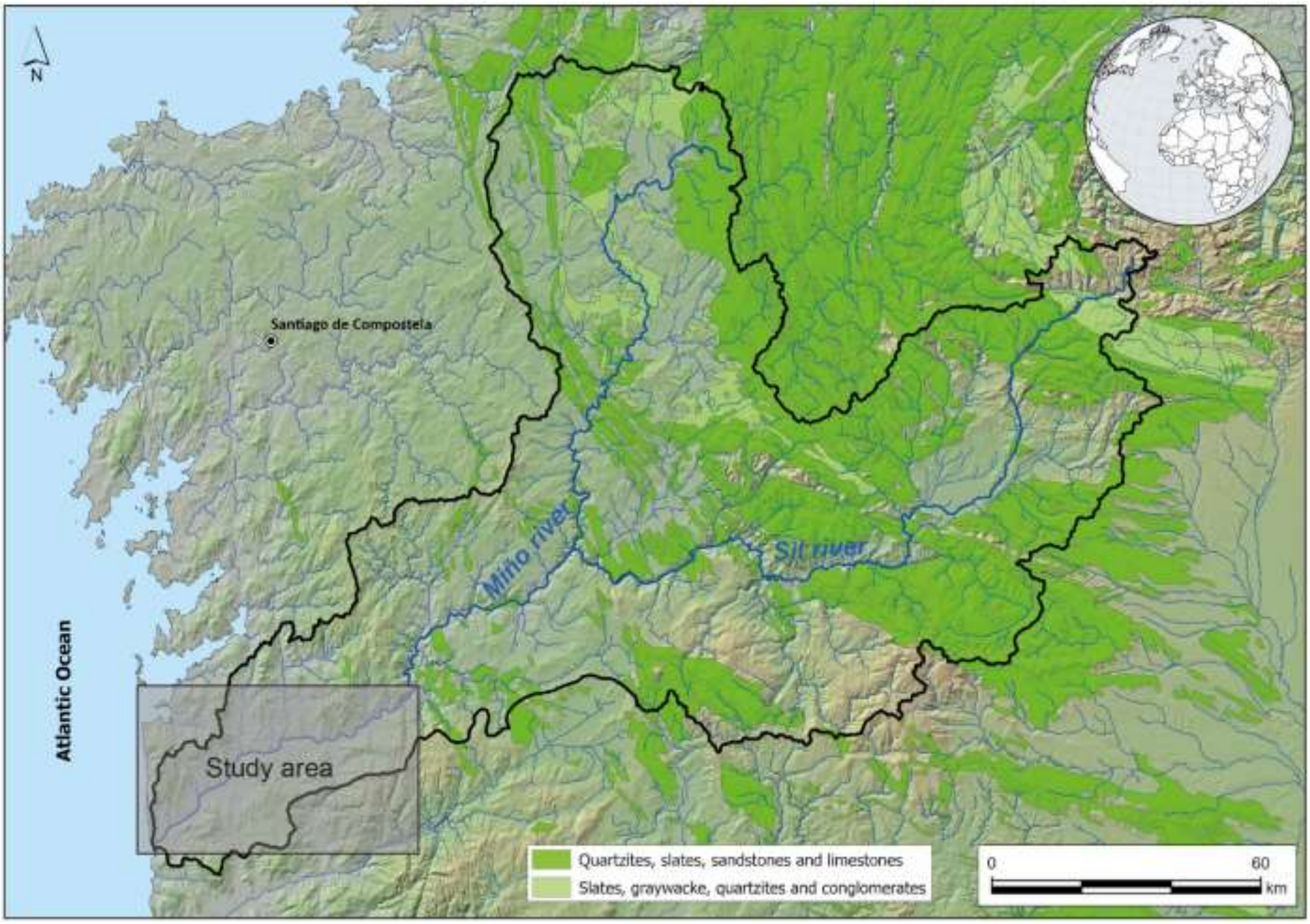
N
Santiago de Compostela
Atlantic Ocean
Miño river
Sil river
Study area
Quartzites, slates, sandstones and limestones
Slates, graywacke, quartzites and conglomerates
0
60
km

Fig. 4

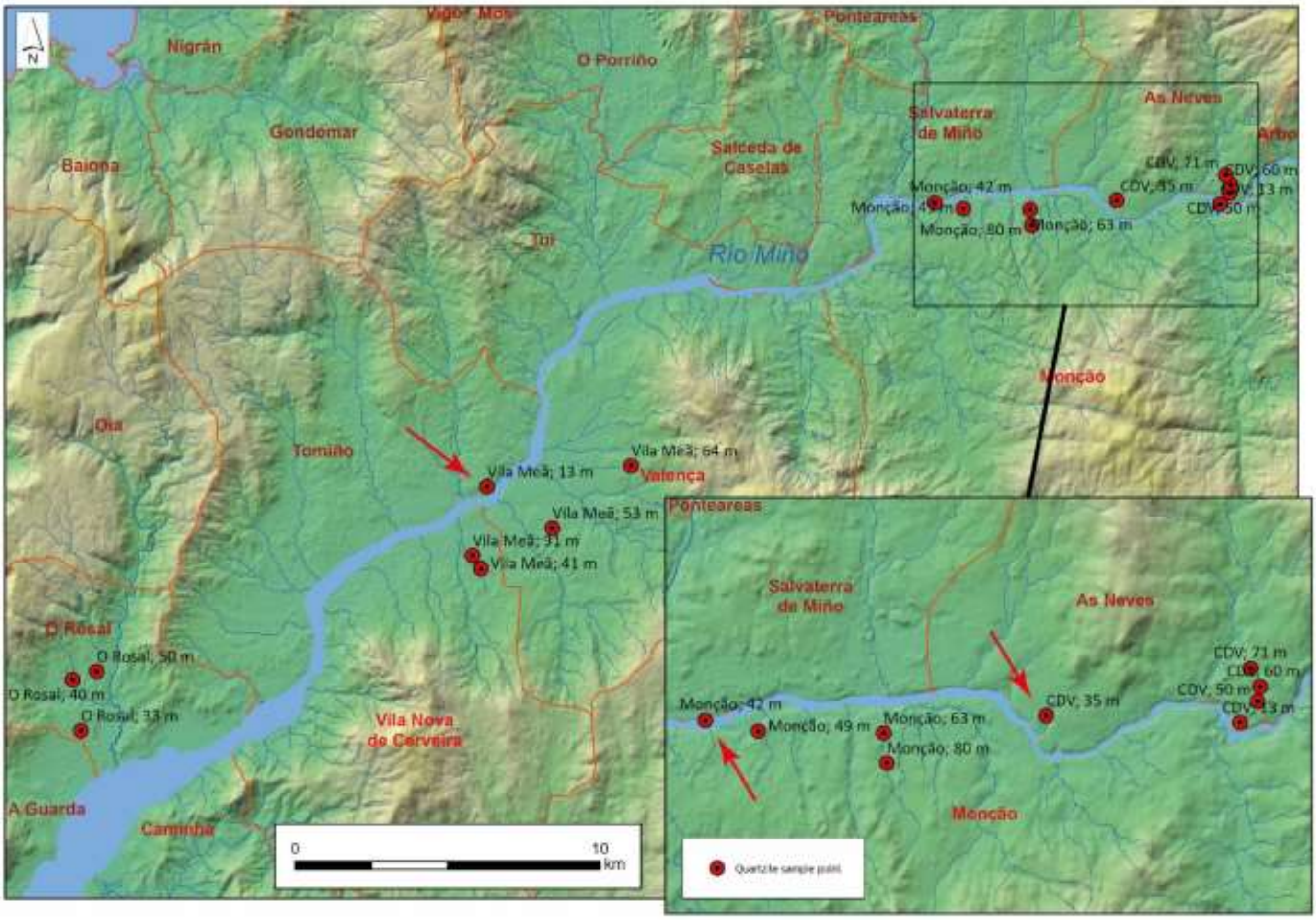
N
Vigo
Mos
Ponteareas
Nigrán
O Porriño
Gondomar
Baiona
Salceda de Caselas
Salvaterra de Miño
As Neves
Arbo
Tui
Rio Miño
Oia
Tomiño
Valença
Monção
O Rosal
A Guarda
Caminha
Vila Nova de Cerveira
Vila Meã; 13 m
Vila Meã; 64 m
Vila Meã; 53 m
Vila Meã; 31 m
Vila Meã; 41 m
O Rosal; 50 m
O Rosal; 40 m
O Rosal; 33 m
Monção; 42 m
Monção; 49 m
Monção; 63 m
Monção; 80 m
CDV; 35 m
CDV; 71 m
CDV; 60 m
CDV; 50 m
CDV; 13 m
0
10
km
Quartzite sample point

Fig. 5