Title: New approaches to examining and interpreting patterns of dental morphological variability in Miocene cricetids.

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Abstract

Here, we present morphometrical analyses on the dental material of *Democricetodon* from the Calatayud-Montalbán Basin. This study incorporates the use of Principal Component Analyses to reduce the number of metrical and morphological variables. Morphological Variability is studied as the morphological distribution of character states using multivariate statistics, and plotted against time. The results indicate that increased dental size is significantly correlated to the Dental Morphological Value in the two *Democricetodon* lineages studied. The rates of change in variables are not linear and periods of higher rates can be correlated with global climatic changes. Morphological Variability is significantly correlated with relative abundances of the studied taxa. High morphological variability, as a proxy of niche breadth, may result from increased intraspecific interferences or from the relaxation of interspecific interactions caused by a decrease in primary productivity.

Keywords: Dental morphology, Variability, Principal Component Analysis, *Democricetodon*, Miocene Spain

Introduction

One of the main advantages to working on fossil small mammals is the large number of available specimens and localities. An example of this kind of record is the Calatayud-Montalbán Basin where Dr. Albert van der Meulen developed an intense and fruitful research program.

Research carried out in the Calatayud-Montalbán Basin was initiated by a Dutch team from the Utrecht University, that later became the core of the Utrecht school of mammal paleontology. Since the early works of De Bruijn (1966, 1967) and Freudenthal (1963), focusing mainly on taxonomy and biostratigraphy, the enormous fossiliferous potential of the basin allowed different workers to open the focus of interest to other palaeontological fields such as palaeoecology and palaeoclimatology. It is on these aspects of palaeontological research that the collaboration of Remmert Daams and Albert van der Meulen produced some of the most important papers published during the 80's and 90's. Papers such as Daams and Van der Meulen (1984) and Van der Meulen and Daams (1992) established the foundation for many later studies in European small mammal paleontology.

Many of the studies based on rodents from the Calatayud-Montalbán Basin were possible because there was a huge amount of data. Those data were the consequence of thorough and accurate descriptive work, including morphological variability represented by the samples (Álvarez Sierra 1987; Daams and Freudenthal 1988; Freudenthal and Daams 1988; López-Guerrero et al. 2008, 2013; Oliver Pérez et al. 2008; García Paredes et al. 2009, 2010; Oliver and Peláez-Campomanes 2013, 2014). Originally, these data were used to build robust systematic studies of the different rodent groups. This knowledge has allowed, as pointed out before, the establishment of a robust systematic framework and important advances on community ecology (Van der Meulen et al. 2005) and paleoclimatology (Van der Meulen and Daams 1992). Most of the published paleoecological works on the Calatayud-Montalbán Basin deal with community structure parameters, such as species richness and ecological diversity, but little attention was paid to dental morphological information and its ecological meaning.

This work is a first attempt to analyze dental morphological variability, in rodents of the Calatayud-Montalbán Basin using multivariate methods in order to correlate the observed variability with ecological traits studied in population ecology, such as niche breadth.

Material and methods

The study deals with the *Democricetodon* material published by Van der Meulen et al. (2003) from the Calatayud-Montalbán Basin. Ages of the localities are after Van Dam et al. (2006 and 2014). The material included belongs to the two lineages of *Democricetodon* defined by Van der Meulen et al. (2003): the lineage *D. hispanicus*-*D. lacombai* and the lineage *D. franconicus*-*D. crusafonti*.

Measurements used in this work are those published by Van der Meulen et al. (2003: Tables 2 to 13). In their work, length and width of each molar were measured perpendicular to each other, following the methods of Daams and Freudenthal (1988). Length represents the maximum length of the measured element, not only that of the occlusal surface. Width represents the maximum width.

To perform the morphological analyses we selected the upper second molar (M2) as our proxy for morphological variability because it is morphologically recognizable and is the intermediate element, thus not affected by edge effects. We prefer to use M2 because the morphological variability is distributed homogeneously in the tooth, whereas in the first and third molars most of their variability is expressed in the anterior or posterior half of the tooth. In order to have statistically representative values, we only used samples with at least ten M2.

Nomenclature used for dental structures is after Daams and Freudenthal (1988). For this study we used the morphological character states (morphotypes) of three dental structures of the M2 (protolophule,

mesoloph and metalophule) because they have more than two character states as published by Van der Meulen et al. (2003). Morphology Values (MV) were calculated by Van der Meulen et al. (2003: Tables, 17, 18, 22 and 23) as follows: each specimen was assigned values on the basis of its character states (e.g. for the mesoloph: long=1, medium=2, short=3 and absent =4). The sum of the values (per trait, per assemblage) is divided by the number of observations and the result is the MV. As indicated before we used Morphology Values (MV) only in samples consisting of more than ten specimens.

In order to have a single Dental Morphology Value (DMV) per *Democricetodon* sample we used ordination techniques. We performed a Principal Component Analysis to ordinate the different *Democricetodon* samples based on Morphological Values calculated for the protolophule, mesoloph and metalophule. The first score was used as the value for morphological variability and to describe its pattern of changes through time.

To describe the morphological variability we calculated the Shannon index (H) using the program PAST, version 3 (Hammer et al. 2001). For each character of the M2 of each sample we calculated the H index, but using the frequency of each character state as if they were species frequencies as in the original formula. The results for each *Democricetodon* assemblage are three variability indexes for each of the morphological characters.

As with the morphological values, we performed a Principal Component Analysis to have a single Morphological Variability Value per *Democricetodon* sample, based on the three diversity indices calculated. The first score has been used as the value for morphological variability and to describe its pattern of changes through time.

We also calculated a Size Value (SV) based on the surface measurements (calculated as length x width) of the first and second upper and lower molars as published by Van der Meulen et al. (2003). We performed a Principal Component Analysis using those measurements as data. The scores of the first principal component were used as a size variable and used to describe patterns of changes through time.

Statistical treatment of the data was performed with IBM SPSS Statistics version 22 (IBM Corp. Released, 2013).

Results and discussion

The calculated scores for each *Democricetodon* sample for Size (SV), Dental Morphology Value (DMV) and Morphological Variability (H) are listed in Table 1. Table 2 shows the Principal Component Analysis results, including the eigenvalues, variance explained by each component and the loadings of each variable on the analysis. For the different analyses and comparisons, we used only the components with eigenvalues higher than 1.

For the proxy of dental size in *Democricetodon*, the first component explains almost 99 percent of the variance, and the contribution to the first component of the four dental elements is positive and strong. Similar results are obtained for the Dental Morphology Value, where the first component explains 77 percent of the variance and the three MV of the different characters all contribute positive and strongly to that component. Finally, the first component of the Morphological Variability (H) explains only 56 percent of the calculated variance. As for the other calculated proxies, the contribution of the three variables is positive for the first component, but the protolophule H has lower loading than the other two variables. In this case the second component is strongly correlated with the protolophule H, as a result of several assemblages with low H, such as that of *Democricetodon jordensi* from Valdemoros 3B, where only the posterior protolophule character state is present.

Both *Democricetodon* lineages show a strong size increase. However, the size increase is not regular as previously observed by Van der Meulen et al. (2003) for individual measurements. This differential rate

may result from environmental changes. There is a high rate of size change during the early Miocene in the *Democricetodon hispanicus*-*D. lacombai* lineage, and a second, more evident, high rate of increase in size between 15 and 14 Ma, in both lineages. Although it is not clear what environmental change could be related with the former higher rate, the second rapid change in size could be linked to the strong drop in global temperatures characterizing the Middle Miocene Climatic Transition (MMCT, Holbourn et al. 2007; Mourik et al. 2010). The increase in size observed in the *D. hispanicus*-*D. lacombai* lineage correlates well with the size increase observed in the *Megacricetodon bavaricus* lineage from the German and Swiss Molasse (Abdul Aziz et al. 2008, 2010; Reichenbacher et al. 2013). The main difference is that in the latter studies the increase is gradual and linear, while in our case the assumption of linearity is falsified. Studying other cricetid species co-occurring with *Democricetodon* we observed that *Megacricetodon primitivus* does not show any significant increase in size during the early Miocene in the Calatayud-Montalbán Basin (Oliver and Peláez-Campomanes 2014), which indicates that the size increase in each lineage responded in different ways to the same environmental factor.

Figure 1 compares the size increase through time with the morphological change (using the Dental Morphological Value) observed in the M2 of the two *Democricetodon* lineages. This reveals some noticeable differences between them. While the *D. franconicus*-*D. crusafonti* lineage shows a very similar distribution pattern between size and DMV, the *D. hispanicus*-*D. lacombai* lineage shows a different pattern for size and DMV. Size increase between 16.20 and 14.80 Ma can be considered close to linear in the *D. hispanicus*-*D. lacombai* lineage. By contrast, the pattern observed in the DMV shows a strong increase in its values around 15.75 Ma, indicating a rapid change in morphology. Size and DMV are significantly correlated in both lineages (Pearson's $r=0.652$, $p<0.006$ for *D. hispanicus*-*D. lacombai* lineage and $r=0.940$, $p<0.0001$ for the other lineage), and therefore the rapid change in DMV around 15.75 Ma represents an unusual situation. The explanation of this rapid morphological change could lie in an expansion of the northern environments towards the Iberian Peninsula, as indicated by the entrance of northern immigrants. This corresponds to an increase of the species richness and the number of cricetid species present (Van der Meulen et al. 2005, 2011 and 2012), and therefore to a possible increase in interspecific competition and the ecological displacement of the lineage to a slightly different niche, as can be inferred from the different dental morphology configuration indicated by the higher DMV.

These results demonstrate the way the two *Democricetodon* lineages evolved during the Aragonian in the Calatayud-Montalbán Basin, and the hypothesized causes of those changes. However, the enormous amount of morphological data available has allowed us to investigate the variability of different morphological traits through time and try to relate them to niche breadth, an important ecological characteristic of populations.

Although the amplitude and the timing are different, the Dental Variability (DV) calculations in the two lineages through the Aragonian in the Calatayud-Montalbán Basin, show similar patterns (Fig. 2). The *Democricetodon hispanicus*-*D. lacombai* lineage shows a strong increase in DV, that reaches its maximum variability around 16.2 Ma (local zone Cb of Van der Meulen et al. 2012), and remaining high till approximately 15.85 (local zone Db), where it drops again. The *Democricetodon franconicus*-*D. crusafonti* lineage shows a similar pattern, but more than one million years later, and with a larger amplitude. The variability increases between 16 and 15 Ma (From Da to Dc), reaching its maximum variability during local zone Dd (between 14.8 to 14.1) of Van der Meulen et al. (2012). During this period and around 14 Ma there are three maxima peaks on the variability curve shown in Figure 2, indicating some fluctuations of environmental conditions as will be discussed below. Notably, Figure 2 shows that there is a significant relationship between variability and relative abundances in both lineages ($r=0.523$, $p<0.037$ for the *D. hispanicus*-*D. lacombai* lineage and $r=0.667$, $p<0.0001$ for the *D. franconicus*-*D. crusafonti* lineage). The maxima of the variability and relative abundances curves in the two lineages coincide, despite that relative abundance is on average higher in the *D. franconicus*-*D. crusafonti* lineage.

Two important questions arise from these results. First, how can this morphological variability be interpreted? Second, to what extent does the positive correlation between Dental Variability and relative

1 abundances have a biological meaning? There is a general agreement that dental morphology in mammals
2 is directly related to food preferences and that small variations in morphological dental traits could be
3 correlated with changing resources (Denys 1994; Evans et al. 2007). Here we go one step further and
4 propose, as a working hypothesis, that the morphological dental variability of an assemblage could be
5 correlated with variability in the resources used by the fossil population. We hypothesize that the
6 variability shown by a fossil sample in dental morphology represents, at least partly, the variability in the
7 resource uses of the living population or successive populations represented by the fossil sample studied.
8 Therefore, and answering our first question, the calculated Dental Variability is assumed to be a useful
9 proxy for niche breadth.

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11 The second question thus can be rewritten in a different way: Are there biological explanations for the
12 positive correlation between niche breadth and relative abundances? This is a difficult question related to
13 resource partitioning, on which ecologists have been working for decades, producing several ecological
14 theories; such as the theory of island Biogeography of MacArthur and Wilson (1967), the resource-
15 breadth hypothesis of Brown (1984), and works dealing with interspecific and intraspecific density-
16 dependent habitat selection in small mammals (Abramsky et al. 1990; Jorgensen 2004; Poindester 2012).

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18 The patterns shown in Figure 2 can be interpreted as variation in the niche breadth of the two
19 *Democricetodon* lineages through time. The maxima of Dental Variability indicate periods of maxima in
20 niche breadth. According to the density-dependant habitat selection hypothesis of Rosenzweig (1991),
21 habitat range is dependent on species density because of strong intraspecific interactions. In our record
22 increase in DV can be interpreted as the result of an increase population size. The only available variable
23 in fossil associations that might have some relationship to species density is the relative abundance.
24 Correlation of the DV and relative abundance may support this hypothesis. The correlation between H
25 and relative abundance is significant even calculating the partial correlation between these two variables
26 and the number of M2s as the control variable ($r=0.591$, $p<0.008$ for *D. hispanicus*-*D. lacombai* lineage
27 and $r=0.552$, $p<0.0001$ for the *D. franconicus*-*D. crusafonti* lineage). This indicates that differences in
28 the sampling effort or preservation conditions in the studied sections are not a dependent factor. This
29 correlation is an unexpected result since there are a high number of factors that can affect the distribution
30 of specimens in a fossil association. Relative abundance represents the proportion of the number of
31 specimens of the different species (in our case calculated as the number of first and second upper and
32 lower molars for each species) over the total number of specimens of the fossil assemblage (Daams et al
33 1999c). Most fossil associations of small mammals result from predator accumulation and later filtering
34 by the action of taphonomic processes (Andrews 1990). Therefore, each fossil assemblage could represent
35 a very different sample of the original community. The Calatayud-Montalbán record, provided by Daams
36 et al. (1999a, 1999b), and Van der Meulen et al. (2012) is, in general, quite homogeneous in
37 sedimentological conditions, and has been sampled with the same excavation methodology, considerably
38 reducing differences among assemblages in taphonomical biases. To determine the existence of an
39 increase of the species density we have to accept that relative abundance reasonably estimates relative
40 density of the recorded taxa in the successive extinct communities. Although there is no easy way to test
41 this, a strong relationship between relative abundance and past density seems, in our opinion, not
42 probable. Accordingly, the correlation between DV and relative abundance is a weak support of the
43 density-dependant habitat selection hypothesis of Rosenzweig (1991) as the explanation for the observed
44 variability patterns in the two *Democricetodon* lineages.

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46 The two lineages express their maximum of relative abundance in periods of strong climatic changes
47 (Daams et al. 1999c; Van der Meulen et al. 2005), such as the pronounced decrease of temperatures that
48 occurred approximately between 15 and 14 Ma (Holbourn et al. 2007). According to the Species-Energy
49 Theory of Wright (1983), the decrease in primary productivity (caused by a decrease in temperature)
50 reduces carrying capacity and therefore the number of species. In the Calatayud-Montalbán rodent record,
51 a decrease in species richness is observed in the same periods with high DVs (Daams et al. 1999c).
52 Therefore, the increase in relative abundance could be explained by the decrease in the observed number
53 of species instead to a, less probable, increase in population density of the species. We interpret this
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correlation as the result of ecological interaction within the extinct *Democricetodon* populations. The increase of niche breadth inferred based on an increase in morphological dental variability may be explained by either stronger intraspecific interactions caused by a decrease of productivity or the relaxation of interspecific interactions caused by a decrease in rodent species richness.

These results have to be taken with caution and, before our methods are applied to other fossil records, deeper studies involving different *Democricetodon* records from other basins and other groups of taxa from the same basin are needed since, as demonstrated by Poindexter et al. (2012) rodent species respond differently to various factors associated with habitat use.

Conclusions

The large number of rich successive samples of fossil material of the genus *Democricetodon* from the Calatayud-Montalbán Basin, allowed us to study the morphological variation present in two lineages that evolved in the area during the early and middle Miocene.

This study presents a promising methodology, based on multivariate statistics, to analyse morphological variability and its evolutionary patterns through time. We demonstrate the utility of dental characters not only for taxonomical purposes but also to test palaeoecological hypothesis. The study of the distribution of character states allowed us to determine the morphological evolutionary stage of an association as well as its morphological variability.

In order to analyse simultaneously the different morphological traits (relative proportion of each character state) we used multivariate ordination methods allowing us to propose a new interpretive approach. This methodology has shown to be highly useful to study morphometric patterns and their correlation to the available environmental information, enabling their explanation.

Two different approaches to the study of the morphology have been followed in this work. First approach deals with the distribution of the Dental Morphological Value through time in the two studied *Democricetodon* lineages from the Calatayud-Montalbán Basin. The obtained results indicate a probable character displacement in one of the lineages caused by an increase in interspecific competition inferred on the higher number of cricetid taxa recorded in the same period. The second approach deals with an almost unexplored subject such is the evolution of the morphological variability and its interpretation. The morphological variation has been interpreted as a proxy for niche breadth. The observed evolutionary patterns of morphological variability are interpreted as the results of changes in environmental conditions. The study relates morphological variability (calculated as the principal component of diversity functions of different dental traits, each calculated as the relative proportion of each character state) with relative abundances of successive samples. Our interpretation of the changes in relative abundance of the two *Democricetodon* lineages is that it is mainly driven by changes in the number of species and not to a theoretical increase of population density of the recorded species. The increase in niche breadth, inferred on the increase in morphological variability, has been correlated to periods of decreasing temperature and therefore, plant productivity. The decrease in productivity explains the increase in niche breadth by stronger intraspecific interactions, related to a decrease in carrying capacity, the relaxation of interspecific interactions related to a lower number of rodent species, or a combination of both.

Acknowledgements

This study would not be possible without the continued research of Albert van der Meulen. He has always been a source of ideas and new approaches throughout his palaeontological career. Therefore, we want to specially thank Albert for his inestimable help. Of course, a study like this is not possible without the work of multiple colleagues who collected and studied the material. Thanks to all of them and especially

to Remmert Daams, who for so long was the driving force behind the work done in the Daroca-Calamocha area. We thank the reviewers Dr. Robert Martin, Dr. Laurence Flynn, and Dr. Lars van den Hoek Ostende by their corrections and comments that improved enormously this work. This research was supported by the MICIIN and MINECO, Projects CGL-2008-04200/BTE and CGL2011-28877. The work of A.O. was supported by a FPU Predoctoral Fellowship and the work of VHB by a FPI predoctoral Fellowship.

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Figure captions

Table 1 Scores for the different variables used for the analyses of the two *Democricetodon* lineages from the Calatayud-Montalbán Basin published by Van der Meulen et al. (2003). Abbreviations: R.A., Relative abundances; N., Minimum number of M2 specimens on which are based the morphological variables; H., Shannon index; mes., mesoloph; prt., protolophule; met., metalophule; MV, Morphology Values; DMV, Dental Morphology Value; MA, centered moving average calculated as the mean of the central value combined with the two anterior and posterior values.

Table 2 Result for the Principal Component Analysis including the Eigenvalues, Variance explained by each component and the loadings of each variable introduced on the analysis. We have used the components with eigenvalues higher than 1. Abbreviations: m1, lower first molar; M1, upper first molar; m2, lower second molar; M2, upper second molar; MV, Morphology Values; mes., mesoloph; prt., protolophule; met., metalophule; H., Shannon index.

Figure 1 a Scatter diagram showing size versus age for the two *Democricetodon* lineages from the Calatayud-Montalbán Basin. **b** Scatter diagram showing the Dental Morphology Value versus age for the two *Democricetodon* lineages from the Calatayud-Montalbán Basin. Lines represent the centered moving average with a span of five.

Figure 2 a Scatter diagram showing the Morphological Variability (H) versus age for the two *Democricetodon* lineages from the Calatayud-Montalbán Basin. **b** Scatter diagram showing the Relative abundances versus age for the two *Democricetodon* lineages from the Calatayud-Montalbán Basin. Lines represent the centered moving average with a span of five.

Figure 1

Figure 2

Table 1

	age	locality	R.A. (%)	N (min)	H (Morph. Variability)			MV (Morphology Value)			Average surface				Size (PC1)	DMV (PC1)	DMV (PC2)	H (PC1)	H (PC2)	MA size (PC1)	MA DMV (PC1)	MA H (PC1)	MA R.A.
					mes	prt	me	mes	prt	met	m1	M1	m2	M2									
<i>D.hispanicus-D.lacombai</i>	14.29	VA7E	7	14	0.23	0.83	1.05	3.88	4.50	2.15	3.16	4.05	2.82	2.94	1.789	1.037	-2.478	-1.508	-0.156				
	14.81	VR7	11	23	0.72	0.90	1.37	3.58	4.39	3.00	2.46	3.28	2.28	2.37	0.482	1.198	-0.971	0.084	-0.770				
	14.84	VA3B	8	11	0.69	0.00	0.76	3.54	5.00	1.36	2.33	3.14	2.15	2.18	0.175	0.744	-4.237	-1.899	-2.736	0.387	0.865	-0.844	11.80
	15.50	VL4A	18	26	0.69	0.51	1.33	3.47	4.64	1.91	2.09	2.83	1.97	2.05	-0.250	0.768	-2.908	-0.450	-1.929	-0.043	0.534	-0.679	12.80
	15.68	VA8A	15	18	0.55	1.16	1.09	3.24	4.11	2.39	2.09	2.90	1.97	1.99	-0.261	0.580	-1.407	-0.449	0.582	-0.222	0.207	-0.523	15.00
	15.82	FTE4	12	10	0.50	1.22	0.96	2.20	2.90	2.44	2.16	2.68	1.79	2.07	-0.358	-0.620	0.603	-0.682	1.003	-0.335	-0.045	0.077	19.40
	15.84	COL-D	22	76	0.89	1.50	1.24	2.78	3.14	1.85	1.98	2.70	1.89	2.03	-0.414	-0.435	-0.772	0.865	1.201	-0.296	-0.369	0.299	20.40
	15.86	COL-C	30	132	0.96	1.51	1.28	2.73	2.86	2.05	2.02	2.68	1.97	1.97	-0.390	-0.518	-0.080	1.100	1.118	-0.284	-0.627	0.492	31.00
	15.88	FTE3	23	17	1.09	1.31	0.89	2.44	2.65	2.23	2.13	2.84	2.03	2.03	-0.201	-0.710	0.557	0.518	0.949	-0.251	-0.722	0.537	35.80
	15.88	COL-B	68	26	1.00	1.38	1.05	2.78	2.54	1.62	2.16	3.02	2.05	2.12	-0.058	-0.853	-0.305	0.659	1.006	-0.269	-0.670	0.654	37.60
	15.89	FTE2	36	24	0.84	1.33	0.96	2.54	2.33	2.20	2.07	2.84	1.97	2.01	-0.280	-0.834	0.915	0.128	1.094	-0.209	-0.749	0.358	37.20
	15.91	OR9	31	15	0.96	1.40	0.86	2.71	2.76	1.80	2.04	2.72	2.04	1.96	-0.324	-0.696	-0.313	0.281	1.358	-0.315	-0.719	0.462	38.00
	15.92	VR2B	28	24	0.91	1.47	0.83	3.07	2.48	1.77	2.15	2.91	1.99	2.04	-0.181	-0.652	-0.084	0.204	1.669	-0.400	-0.763	0.543	27.80
	16.10	VR3	27	35	1.17	1.50	1.08	2.61	2.51	2.20	1.96	2.55	1.84	1.89	-0.588	-0.701	0.652	1.181	1.228	-0.471	-0.794	0.765	26.20
	16.11	VR1A	17	82	1.01	1.36	1.22	2.54	2.32	2.00	1.91	2.55	1.82	1.88	-0.628	-0.931	0.630	0.923	0.708	-0.531	-0.907	0.842	24.00
	16.12	VR4BB	28	77	1.09	1.42	1.26	2.52	2.26	1.96	1.91	2.57	1.84	1.85	-0.635	-0.992	0.657	1.236	0.770	-0.769	-1.087	0.793	20.00
	16.15	VR4A	20	69	0.97	1.24	1.18	2.38	2.13	1.70	1.91	2.59	1.83	1.87	-0.621	-1.258	0.484	0.664	0.374	-1.018	-1.271	0.449	20.20
	16.49	ART1	8	41	0.99	1.18	0.76	2.07	2.14	1.43	1.57	2.07	1.53	1.52	-1.373	-1.552	0.156	-0.036	0.802	-1.257	-1.465	-0.103	18.80
	16.63	VL2A	28	19	0.76	1.31	0.66	1.91	2.23	1.37	1.36	1.91	1.26	1.29	-1.830	-1.623	-0.009	-0.540	1.537				
	16.77	SR1	10	14	0.64	0.94	0.26	1.67	2.22	1.07	1.47	1.72	1.31	1.28	-1.824	-1.902	-0.375	-1.836	1.011				
<i>D.franconicus-D.crusafonti</i>	11.87	NOM2	6	16	0.65	0.87	0.48	3.65	4.35	4.00	3.41	4.68	3.27	3.30	2.619	1.673	0.559	-1.518	0.460				
	12.01	SOL	6	11	0.69	1.24	0.69	3.46	3.12	3.45	3.01	4.55	3.00	3.25	2.165	0.671	1.452	-0.709	1.322				
	12.65	TOR3B	5	13	0.52	1.06	0.69	3.79	3.80	3.62	2.93	4.13	2.85	3.02	1.752	1.292	0.693	-1.258	0.878	1.825	1.275	-1.116	9.80
	12.66	TOR1	11	14	0.50	1.06	0.41	3.80	4.14	3.86	2.68	3.93	2.66	2.82	1.320	1.585	0.590	-1.743	1.292	1.546	1.227	-1.041	15.20
	13.25	BOR	21	30	0.61	1.24	1.01	3.70	3.94	3.27	2.77	3.82	2.67	2.70	1.268	1.154	0.006	-0.354	0.919	1.317	1.287	-0.794	26.00
	13.30	MAN	33	67	0.66	1.07	0.57	3.63	4.12	3.76	2.73	3.81	2.69	2.66	1.227	1.432	0.516	-1.142	0.985	1.191	1.251	-0.473	34.80
	13.99	LUM14	60	57	1.02	0.92	1.25	3.35	4.37	2.82	2.67	3.65	2.54	2.61	1.019	0.974	-1.147	0.525	-0.773	1.143	1.042	-0.042	36.20
	14.00	LUM18	49	10	0.94	0.94	1.21	3.40	4.30	3.13	2.85	3.67	2.51	2.62	1.121	1.108	-0.603	0.351	-0.581	1.070	1.019	0.089	37.00
	14.03	LUM12	18	10	1.06	1.01	1.06	3.23	4.00	2.44	2.78	3.63	2.51	2.66	1.080	0.539	-1.181	0.412	-0.236	1.025	0.885	0.339	35.40
	14.04	LUM16	25	19	0.94	1.10	1.09	3.45	3.95	3.32	2.60	3.50	2.53	2.58	0.901	1.040	0.140	0.300	0.088	1.017	0.976	0.038	29.60
	14.06	LUM11	25	34	1.08	0.82	0.97	2.89	4.08	3.26	2.67	3.60	2.55	2.61	1.006	0.763	0.036	0.106	-0.739	0.975	0.961	0.029	29.20
	14.18	LUM9	31	14	0.76	0.90	0.66	3.64	4.21	3.64	2.69	3.59	2.44	2.66	0.977	1.430	0.212	-0.980	0.220	0.863	0.938	-0.171	39.00
	14.20	LUM8	47	39	0.99	1.11	1.02	3.34	3.98	3.41	2.62	3.59	2.49	2.55	0.910	1.034	0.265	0.310	0.194	0.799	0.833	-0.166	43.80
	14.24	VA7G	67	14	0.89	0.85	0.75	2.60	3.47	3.57	2.40	3.36	2.24	2.48	0.520	0.421	1.408	-0.591	-0.168	0.693	0.831	0.027	52.60
	14.27	VA7F	49	27	1.16	1.16	0.78	2.68	3.57	3.56	2.43	3.45	2.32	2.42	0.581	0.514	1.235	0.326	0.576	0.621	0.653	0.427	56.80
	14.29	VA7E	69	89	1.10	1.20	1.29	3.20	3.86	3.11	2.40	3.31	2.33	2.36	0.478	0.755	0.019	1.069	0.022	0.511	0.579	0.512	59.60
	14.30	LUM5	52	22	1.20	1.03	1.24	2.74	3.74	3.35	2.57	3.25	2.40	2.40	0.617	0.541	0.673	1.020	-0.526	0.500	0.690	0.522	59.40
	14.32	LUM4	61	59	1.05	1.08	1.23	3.21	3.63	3.16	2.37	3.22	2.23	2.33	0.358	0.664	0.402	0.738	-0.247	0.430	0.622	0.724	65.20
	14.33	VA7D	66	17	1.01	0.76	0.69	3.25	3.91	3.47	2.45	3.24	2.33	2.33	0.465	0.974	0.476	-0.545	-0.467	0.325	0.494	0.856	64.20
	14.37	LUM3	78	177	1.12	1.13	1.48	2.67	3.59	2.81	2.29	3.14	2.21	2.27	0.233	0.176	0.088	1.335	-0.506	0.210	0.468	0.793	68.20
	14.38	VR11	64	43	1.29	1.12	1.51	2.69	3.48	2.78	2.21	2.87	2.10	2.13	-0.046	0.117	0.186	1.732	-0.706	0.138	0.428	0.859	66.20
	14.39	VA6B	72	29	1.05	1.04	1.23	2.91	3.55	3.07	2.25	2.93	2.13	2.18	0.041	0.410	0.462	0.704	-0.373	-0.008	0.316	1.053	63.00
	14.40	LUM2	51	16	1.19	1.01	1.30	2.71	3.61	3.36	2.23	2.99	2.09	2.13	-0.001	0.461	0.873	1.070	-0.667	-0.016	0.366	0.686	51.80
	14.42	LUM1	50	18	1.00	1.05	1.12	2.76	3.57	3.24	2.02	2.83	2.00	2.06	-0.267	0.413	0.733	0.422	-0.159	0.021	0.328	0.233	49.40
	14.50	VA3F	22	11	0.79	0.52	1.16	3.15	3.21	3.20	2.30	2.94	2.29	2.23	0.192	0.428	1.046	-0.497	-1.737	-0.045	0.250	0.170	40.20
	14.53	VA3E	26	12	0.62	0.89	1.12	2.69	3.07	2.83	2.27	2.97	2.20	2.23	0.137	-0.075	0.815	-0.536	-0.354	-0.024	0.283	0.208	49.40
	14.53	VA6A	52	50	0.99	0.93	1.19	2.41	3.43	2.98	2.04	2.79	2.00	2.03	-0.285	0.023	0.634	0.393	-0.611	-0.024	0.317	0.343	46.60
	14.55	VA7C	83	212	1.08	1.24	1.41	3.11	3.82	2.98	2.24	3.06	2.14	2.20	0.101	0.624	-0.095	1.256	-0.013	-0.110	0.270	0.629	50.20
	14.59	VA7B	64	102	1.17	1.12	1.27	3.11	3.66	3.08	2.11	2.80	1.97	2.03	-0.266	0.586	0.270	1.098	-0.264	-0.192	0.274	0.909	53.00
	14.61	VA1A	26	23	1.15	1.06	1.23	2.48	3.46	3.23	2.05	2.80	2.11	1.99	-0.238	0.193	0.947	0.936	-0.386	-0.136	0.238	0.951	53.60
	14.67	VA8B	66	30	1.08	0.80	1.45	2.83	3.40	2.32	2.04	2.80	1.99	2.06	-0.271	-0.056	-0.434	0.864	-1.472	-0.284</			

Table 2

Component		Initial Eigenvalues			Size Loadings		
		Total	% of Variance	Cumulative %	m1	M1	m2
	1	3.958	98.94	98.94	0.993	0.996	0.994
	2	0.020	0.49	99.43			
	3	0.015	0.37	99.80			
	4	0.008	0.20	100.00			
Component		Initial Eigenvalues			DMV Loadings		
		Total	% of Variance	Cumulative %	Mes.	Prt.	Met.
	1	2.322	77.41	77.41	0.908	0.875	0.856
	2	0.409	13.63	91.04	-0.081	-0.398	0.494
	3	0.269	8.96	100.00			
Component		Initial Eigenvalues			H (Variability) Loadings		
		Total	% of Variance	Cumulative %	Mes.	Prt.	Met.
	1	1.685	56.17	56.17	0.859	0.534	0.814
	2	0.873	29.10	85.27	-0.165	0.839	-0.376
	3	0.442	14.73	100.00			