

Increasing the research potential of digitized fossils: A pilot study using Specify to attach stable isotope data to vouchered museum specimens

Sean M. Moran, Richard C. Hulbert, Warren H. Brown, Bruce J. MacFadden
Florida Museum of Natural History, University of Florida



FLORIDA MUSEUM
OF NATURAL HISTORY

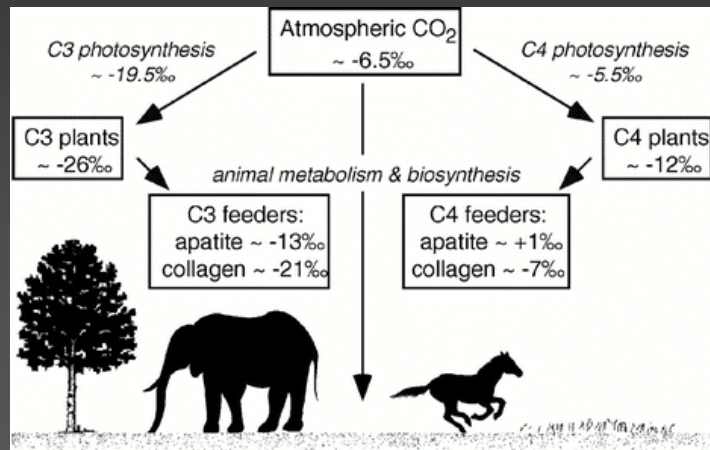


iDigBio
Integrated Digitized Biocollections



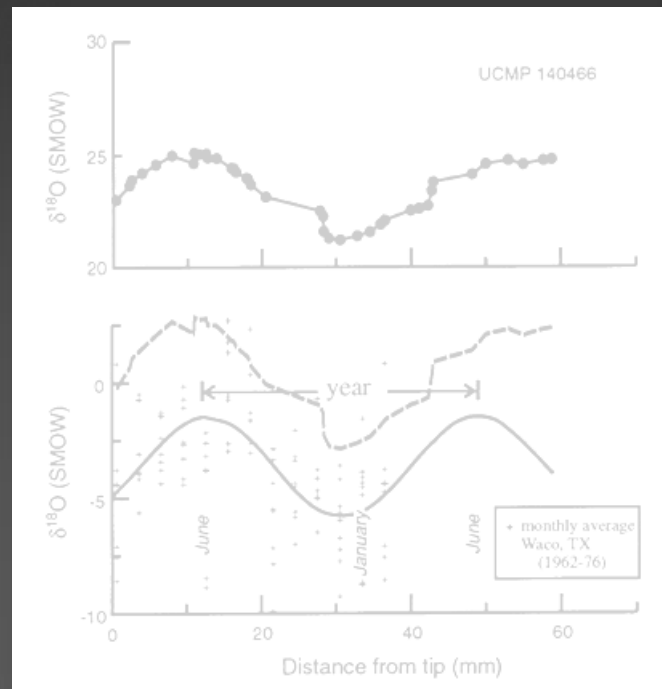
Stable Isotopes in Vertebrate Paleontology

Paleodiet ($\delta^{13}\text{C}$)



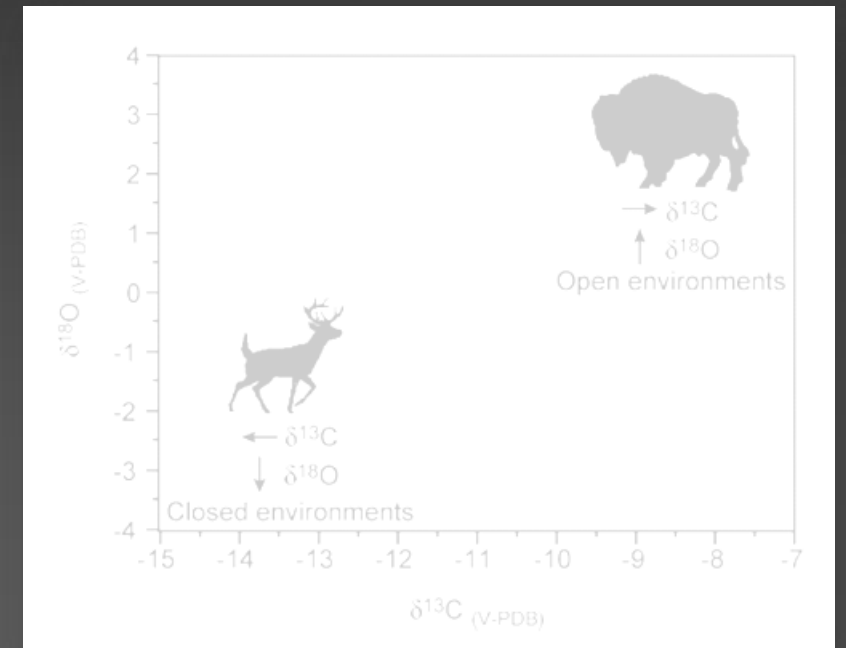
Koch, 1998

Paleoclimate ($\delta^{18}\text{O}$)



Sharp and Cerling, 1998

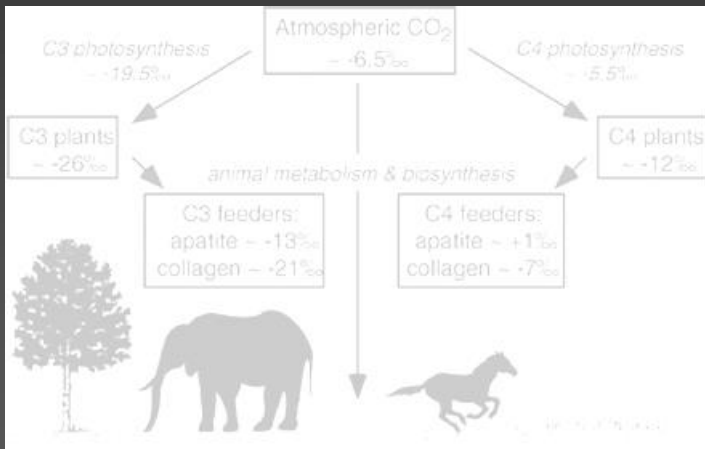
Paleoenvironmental Reconstruction ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$)



Feranec and MacFadden, 2006

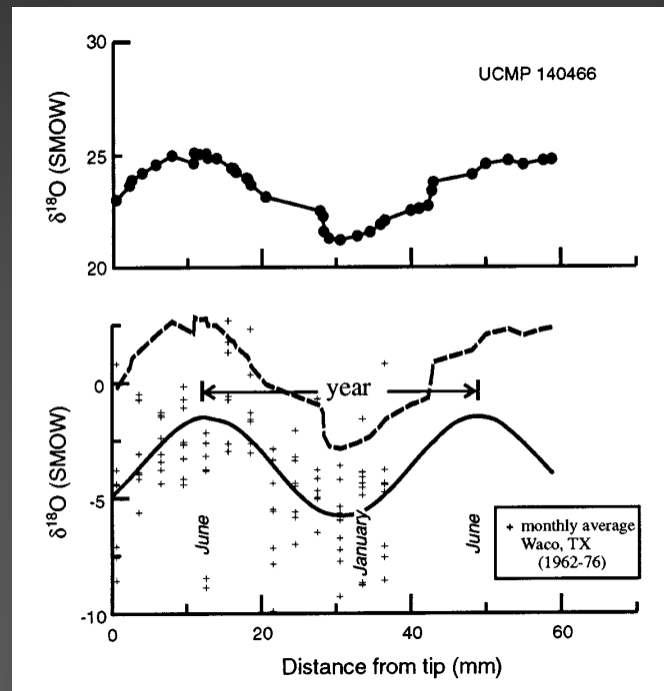
Stable Isotopes in Vertebrate Paleontology

Paleodiet ($\delta^{13}\text{C}$)



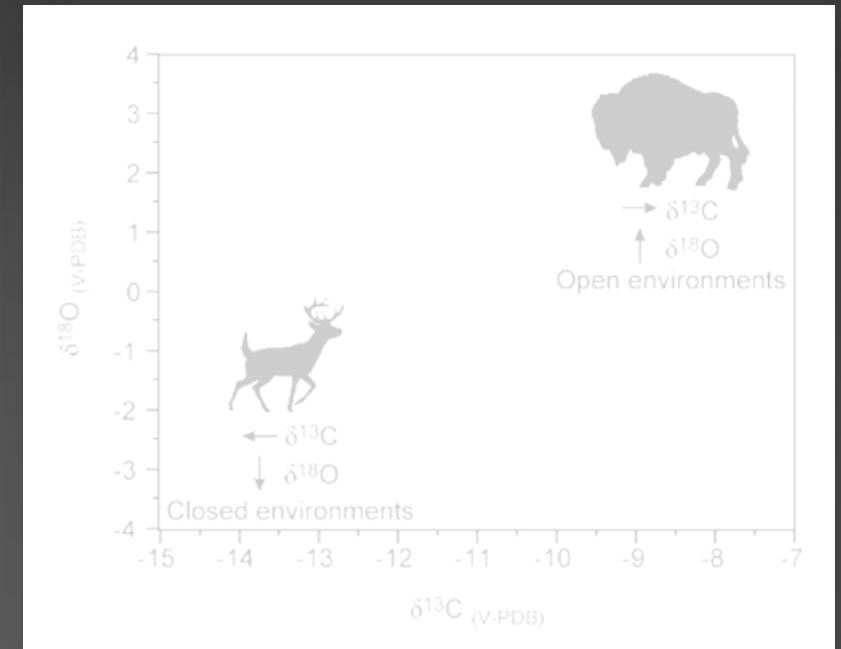
Koch, 1998

Paleoclimate ($\delta^{18}\text{O}$)



Sharp and Cerling, 1998

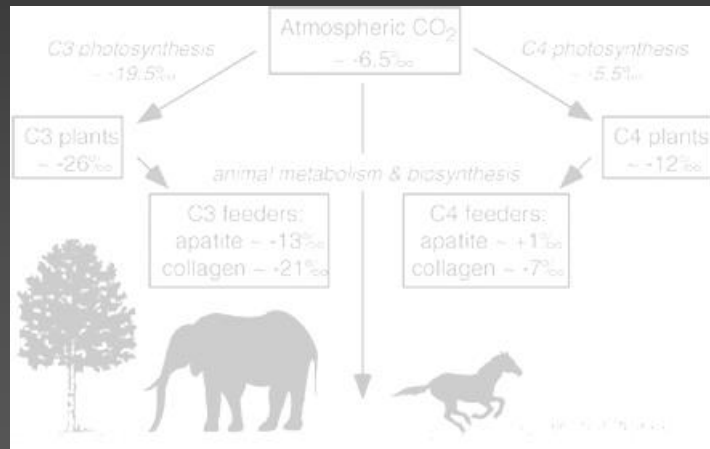
Paleoenvironmental Reconstruction ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$)



Feranec and MacFadden, 2006

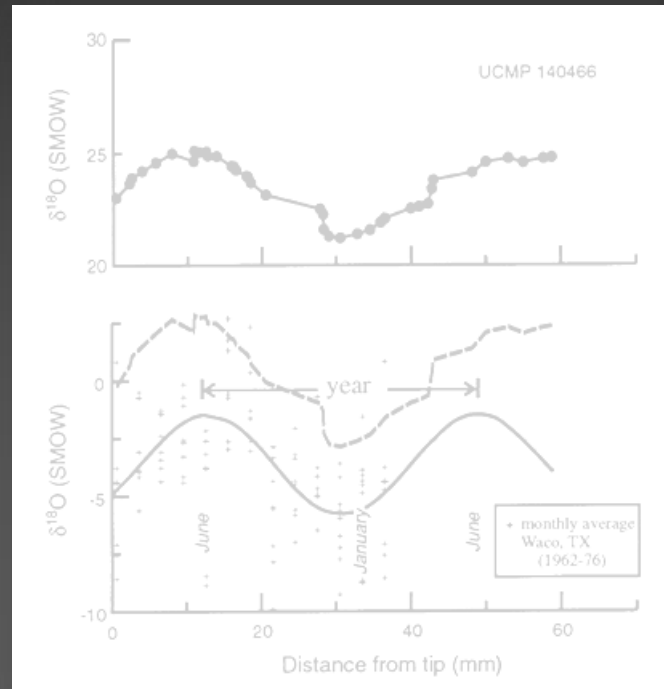
Stable Isotopes in Vertebrate Paleontology

Paleodiet ($\delta^{13}\text{C}$)



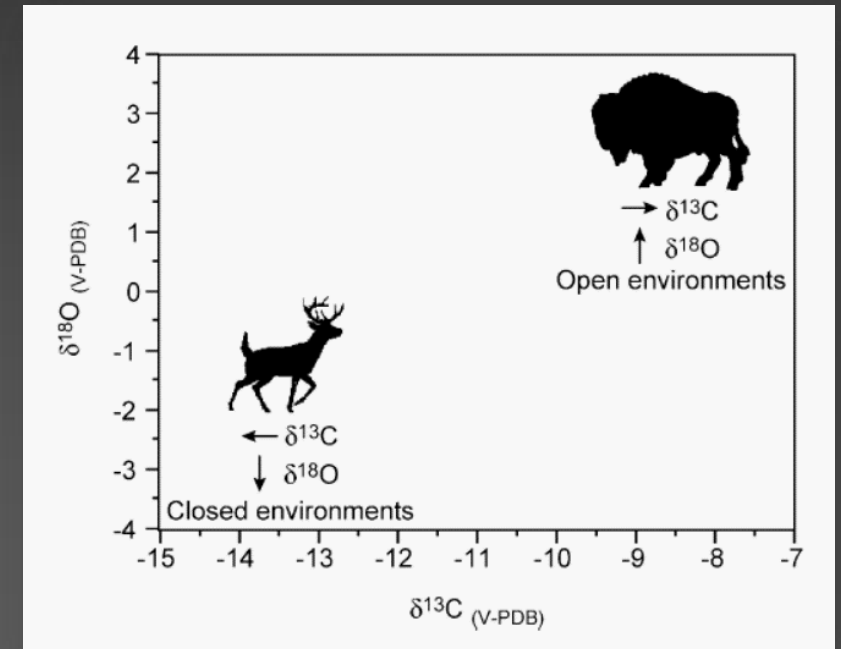
Koch, 1998

Paleoclimate ($\delta^{18}\text{O}$)



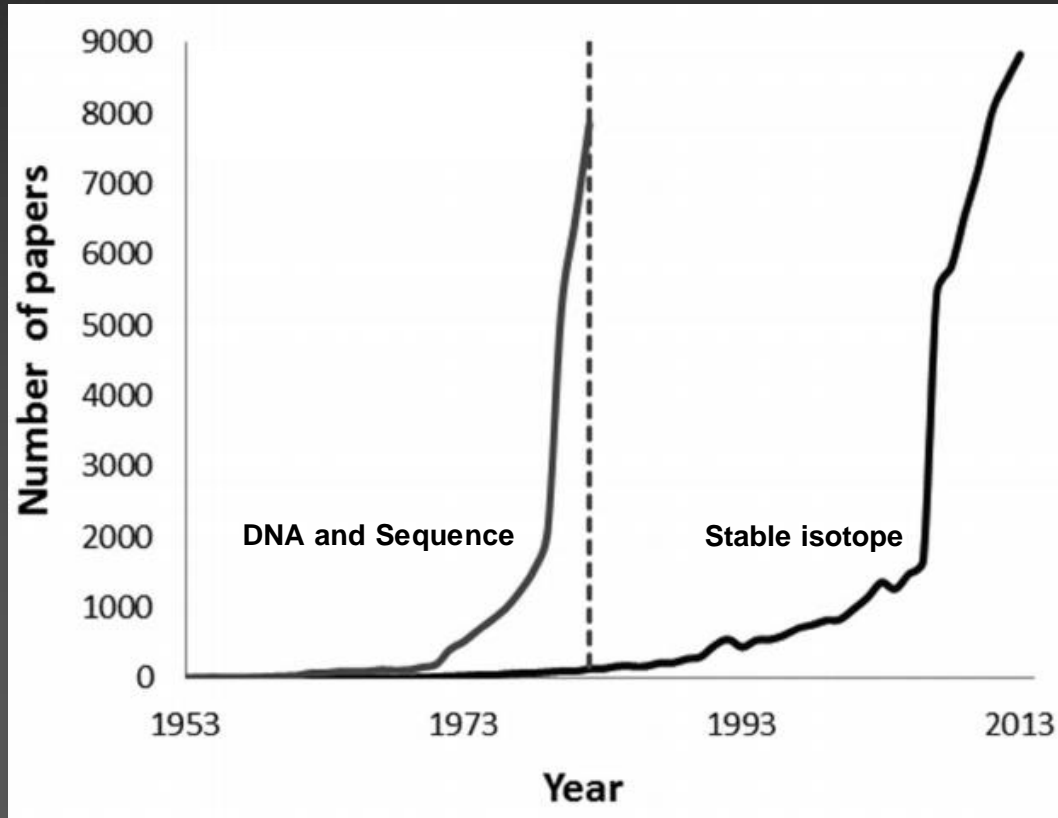
Sharp and Cerling, 1998

Paleoenvironmental Reconstruction ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$)



Feranec and MacFadden, 2006

The Need for a Global Stable Isotope Database



Glut of Stable Isotope Data

Appendix Continued.

Sample no.	Museum no.	Taxon
RSF04118	UF 68840	Pseudhipparion skinneri
RSF04119	UF 68843	Pseudhipparion
RSF04120	UF 92963	Pseudhipparion
RSF04121	UF 92969	Pseudhipparion
RSF04122	UF 96521	Prototippus
RSF04123	UF 68824	Prototippus
RSF04124	UF 68828	Prototippus
RSF04125	UF 68830	Prototippus
RSF04126	UF 68834	Prototippus
RSF04127	UF 68835	Prototippus
RSF04128	UF 68837	Nannippus
RSF04129	UF 68838	Nannippus
RSF04130	UF 54504	Nannippus
RSF04131	UF 63999	Nannippus
RSF04132	UF 96239	Nannippus
RSF04133	UF 92975	Nannippus
RSF04134	UF 92990	Nannippus
RSF04135	UF 92940	Nannippus
RSF04136		
RSF04137		

Sample*	Distance ^b δ ¹⁸ O (‰ SMOW)	δ ¹⁸ O
Late Eocene		
UF 206800 MS A	0.83	23.96
	1.88	23.16
	3.13	
	4.38	
	5.63	
	6.88	
UF 207890 MS B	1.88	
	3.13	
	5.63	
UF 206568 MS A	0.83	
	1.88	
	3.13	
	4.38	
UF 201881 MS A	0.83	
	1.88	
	3.13	
	4.38	
UF 208174 MS A	0.83	
	1.88	
	3.13	
	4.38	

Taxon	UF no.*	δ ¹³ C	Percent C ₄
Pan*			
	14770+	-8.2	87
	14780+	-9.5	92
	103570	-10.8	17
	148668	-12.2	
	148670+		
	92513		
	92528		
	92522		
	92563		
Rock Springs			
Mammals	4385		
	4473		
	4897		
	119828		
Mammals	4385+		
	4896		
	119827+		
Mammals	48974+		
	48975+		
	48970		
	148673+		
Equus			
Tapiro			
Odocoileus			
Odocoileus			
Horseshoe Springs			
Mammals			

Lat. (°)	N	\bar{x} (‰)	δ (‰)	δ ¹³ C	δ ¹⁸ O
68 N	2	-10.0	0.5		
65 N	1	-9.5			
64 N	1	-11.5			
51 N	1	-11.1			
48 N	1	-10.9			
44 N	2	-7.0			
43 N	1	-8.3			
40 N	2	-9.3			
36 N	1	-8.4			
35 N	5	-3.0			
34 N	1	-5.5			
33 N	3	-5.1			
32 N	14	-0.2			
30 N	6	-4.7			
28 N	13	-1.6			
27 N	5	-1.7			
	1	-2.4			

N	\bar{x} (‰)	δ (‰)	δ ¹⁸ O	Obs. Range (‰)
19.0	0.1			-18.0 to -17.0

Teeth ID	Taxon	Site	Teeth position	n subsamples	Mean δ ¹³ C (‰ V-PDB)	SD (‰)	Mean δ ¹⁸ O (‰ V-SMOW)	SD (‰)
P2787.1	Trigodon schreber	Bad	right M1	6	-8.6	0.2	18.2	1.1
P2787.2	Equus	ISW	right P4	7	-8.7	0.0	20.8	0.4
P2787.3	Equus	Irish Springs	right P4	13	-9.1	0.1	18.3	0.6
CP 71-1	Merolagus	Parson Ranch/Alexander Ranch	right P4	14	-8.8	0.0	20.7	0.5
P 2549.5	Merolagus	Bad	right M1 or M2	7	-8.2	0.0	20.5	0.1
P 2549.8	Merolagus	Bad	right M1 or M2	3	-8.6	0.1	20.7	1.2
P 2549.8	Merolagus	Bad	right M1 or M2	4	-8.6	0.1	20.5	1.3
P 2549.4	Merolagus	Combs/Levee Creek	right P4 or M7	3	-8.6	0.1	20.5	1.2
P 1585.1542	Merolagus	Combs/Levee Creek	right P4 or M7	3	-8.6	0.1	20.5	1.2
P 1585.1546	Merolagus	Combs/Levee Creek	right P4 or M7	3	-8.6	0.1	20.5	1.2

we were sub-sampled perpendicular to the growth axis at intervals of 1.25 mm and the outer layer of enamel and adhering dentin were removed under a binocular microscope with a dental drill and a razor blade, respectively. Because of differences in tooth size and crown height, the number of analyzable subsamples varied among the analyzed teeth from 1 to 20. For the analyses of the carbonate component of enamel, powdered samples were treated with H₂O₂ to remove organic contaminants and with an acetic acid-calcium acetate buffer to remove diagenetic carbonates (Koch et al., 1997). A recent study con-

(p = 0.001 t-test; p = 0.002 Mann-Whitney test) and rhinos (p = 0.04 t-test; p = 0.01 Mann-Whitney test) separately. However, when horse and rhino data are pooled into perisodontology datasets, average Eocene (-8.8 ± 0.3‰) and Oligocene (-9.0 ± 0.3‰) δ¹³C values are not statistically different (p = 0.15 t-test; p = 0.76 Mann-Whitney test). With respect to variability, intra-tooth isotope profiles generally show a very small δ¹³C range in both the Eocene and Oligocene (Figs. 3 and 4). However, variance in perisodontology δ¹³C is probably higher in the Oligocene than in the Eocene (p = 0.001 F-test; p = 0.082 Levene test).



Typical Specify data record

Collection Object

Specify Number: 60976 Catalog No: 27101 Old Cat No:
Field Number: Source: UF Accession: *i*
Nature of Spec: P2, left upper Nat of Spec Abb:
Status of Spec: IN COLLECTION Specimen Type: FIGURED
Cataloger: UNKNOWN *i* Cataloged Date:
Remarks: R. C. HULBERT (2005), BULLETIN OF THE FLORIDA MUSEUM OF NATURAL HISTORY 45(4):476, FIG. 71 *i*

Determinations

Taxon: Tapirus webbi *i* Current
Preferred Taxon: Tapirus webbi
Qualifier: Modifier: Type Status: None
ID Date: Identifier: *i*
Orig Identifier:

Collecting Information

Start Date: 1980 End Date: Collected Date: 1980
Locality: LOVE BONE BED, AL001, North America USA Florida Alachua *i* 0
Collector (verb): FLORIDA STATE MUSEUM CREW

Collectors *i*

First Name	Middle Initial	Last Name	Remarks
		Florida State Museum Crew	

Col Obj Attribute

Provenience: NFD Stratigraphy:
 Sampled Sampled for Stable Isotopes Sampled for REE Sampled for Radiocarbon Other Sampling
Scanning:
Count Amount: 1

Preparations

Prep Type: fossil Count: 1 Is On Loan Show Loans 0
Nature of Spec: Nat of Spec Abb:
Fossil ID: tooth, upper, premolar *i*
Fossil ID Agent: *i*

Our insertion of isotope data fields

Preparation Attribute

Side: left Serial Number: second
Completeness: complete Portion Present: all
Ontogeny: Ontogeny Basis:
Sex: unknown Sex Determination Basis:
Pathology: none Post mortem bone modification: none
Fossil ID Date: 06/20/2016 delta C-13: -13.1
carbon isotope ... V-PDB delta O-18: 2.9
oxygen isotope ... V-PDB isotope sampling method: enamel; single
Remarks: *i*

Collection Object Citations

Reference Work: Isotopic discrimination of resource partitioning among ungulates in C3-dominated communities from the Miocene of Florida and California *i*
 Is Figured
Figure Number:
Table Number:
Remarks: *i*



Typical Specify data record

Collection Object

Specify Number: 60976 Catalog No: 27101 Old Cat No:

Field Number: Source: UF Accession:

Nature of Spec: P2, left upper Nat of Spec Abb:

Status of Spec: IN COLLECTION Specimen Type: FIGURED

Cataloger: UNKNOWN Cataloged Date:

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Preferred Taxon: Tapirus webbi

Qualifier: Modifier: Type Status: None

ID Date: Identifier:

Orig Identifier:

Collecting Information

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Locality: LOVE BONE BED, AL001, North America USA Florida Alachua

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Collectors

First Name	Middle Initial	Last Name	Remarks
		Florida State Museum Crew	

Col Obj Attribute

Provenience: NFD Stratigraphy:

Sampled Sampled for Stable Isotopes Sampled for REE Sampled for Radiocarbon Other Sampling

Scanning:

Count Amount: 1

Preparations

Prep Type: fossil Count: 1 Is On Loan Show Loans

Nature of Spec: Nat of Spec Abb:

Fossil ID: tooth, upper, premolar

Fossil ID Agent:

Our insertion of isotope data fields

Preparation Attribute

Side: left Serial Number: second

Completeness: complete Portion Present: all

Ontogeny: Ontogeny Basis:

Sex: unknown Sex Determination Basis:

Pathology: none Post mortem bone modification: none

Fossil ID Date: 06/20/2016 delta C-13: -13.1

carbon isotope ... V-PDB delta O-18: 2.9

oxygen isotope ... V-PDB isotope sampling method: enamel; single

Remarks:

Collection Object Citations

Reference Work: Isotopic discrimination of resource partitioning among ungulates in C3-dominated communities from the Miocene of Florida and California

Is Figured

Figure Number:

Table Number:

Remarks:

- New preparation attributes can be added for each tooth of a given specimen (e.g., m1, m2, and m3 of a dentary) with isotope data attached

An example: Easily queried records

Collection Object

Taxon

Locality

Chronostratigraphy

Paleo context

Collection object attribute
Storage

Preparation attribute

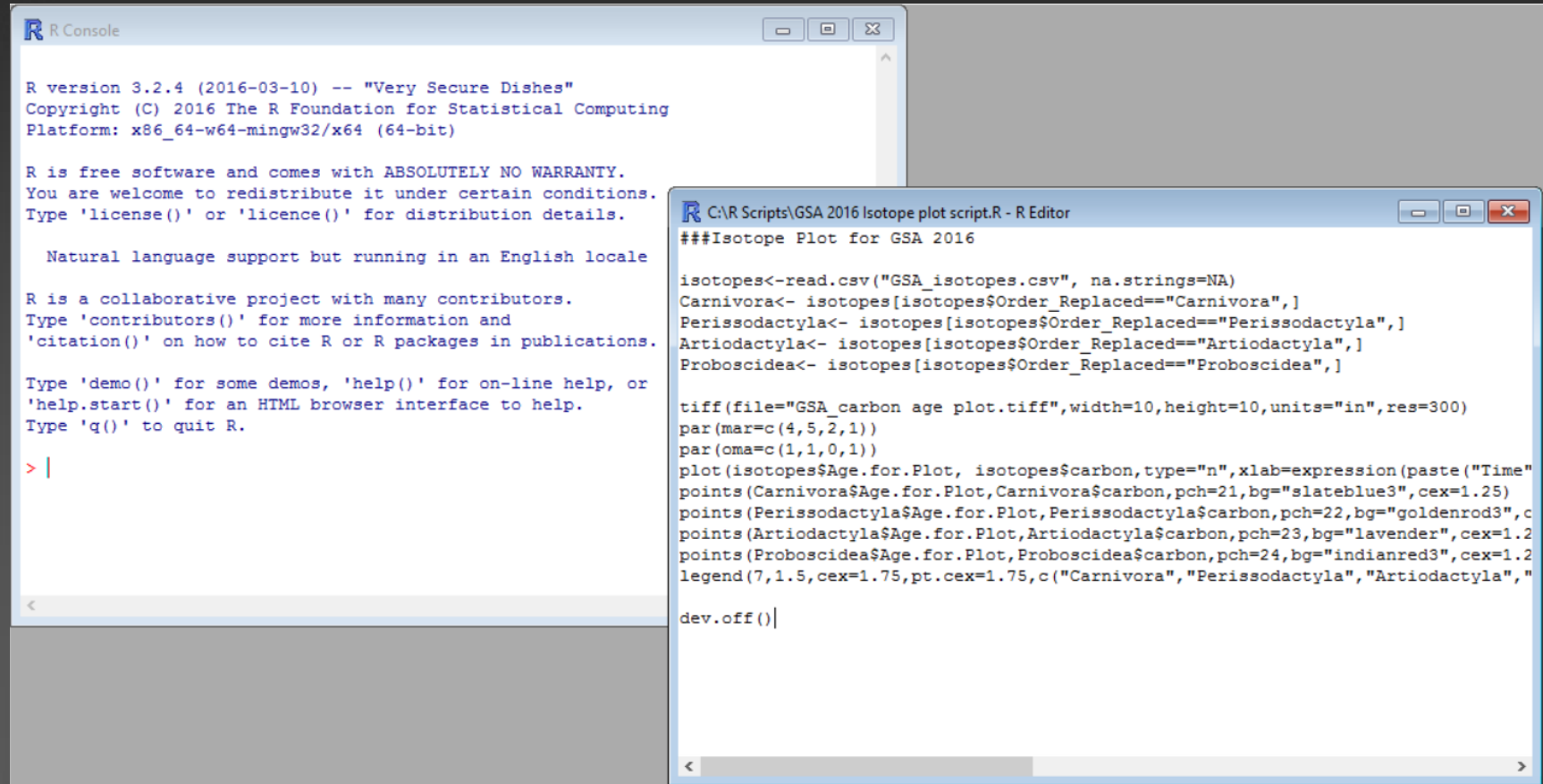
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CO	Catalog No	<input type="checkbox"/>	=	
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CO	Nature of Spec	<input type="checkbox"/>	Contains	
Tax	Class	<input type="checkbox"/>	Contains	
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Tax	Family	<input type="checkbox"/>	Contains	
Tax	Genus	<input type="checkbox"/>	Contains	
Tax	Species	<input type="checkbox"/>	Contains	
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Loc	Datum	<input type="checkbox"/>	Contains	
Loc	Latitude1	<input type="checkbox"/>	=	
Loc	Longitude1	<input type="checkbox"/>	=	
CS	Series/Epoch	<input type="checkbox"/>	Contains	
PC	Land Mammal Age	<input type="checkbox"/>	Contains	
PC	Faunal Zone	<input type="checkbox"/>	Contains	
CoA	Sampled for Stable Isotopes	<input type="checkbox"/>		
Sto	Full Name	<input type="checkbox"/>	Contains	
PrA	Side	<input type="checkbox"/>	=	
PrA	Serial Number	<input type="checkbox"/>	=	
PrA	delta O-18	<input type="checkbox"/>	=	
PrA	oxygen isotope standard	<input type="checkbox"/>	Contains	
PrA	delta C-13	<input type="checkbox"/>	>=	-40
PrA	carbon isotope standard	<input type="checkbox"/>	Contains	
PrA	isotope sampling method	<input type="checkbox"/>	=	
PrA	Preparation Attribute/Remarks	<input type="checkbox"/>	Contains	

An example: Output to Excel file

	A	B	C	D	E	G	H	I	K	L	N	P	Q	R	S	T	Y	Z	AA	AB	AC	AD	AE	
1	Source	Catalog Number	Specify Number	Class	Order	Family	Genus	Species	Nature of Site	Site	Site Key	Latitude	Longitude	Series/Epoch	Land Mammal	Faunal Zone	Full Name	Side	Serial Number	delta O-18	oxygen isotope	delta C-13	carbon isotope	
2	UF/FGS	5107	18682	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	molar, left	SANTA FE	CO071	29.83575	-82.6832	Pleistocene	Blancan or	Rancholabre	tooth, upp left	tooth, upp left	none/NA				-9.7	V-PDB
3	UF	2855	36643	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	M2, right upper	REDDICK 1	MR016	29.36123	-82.1856	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	second				-14	V-PDB
4	UF	2991	36991	Mammalia	Artiodactyla	Camelidae	Palaeolama		dentary, left	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low left	tooth, low left	first	29	V-SMOW		-8.4	V-PDB
5	UF	3224	37183	Mammalia	Artiodactyla	Tayassuidae	Mylohyus		dentary, left	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low left	tooth, low left	third	31.7	V-SMOW		-7.6	V-PDB
6	UF	3264	37223	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	maxilla, with	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	first	29.2	V-SMOW		-10.5	V-PDB
7	UF	3265	37224	Mammalia	Artiodactyla	Cervidae	Odocoileus		dentary, right	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low right	tooth, low right	second	30.3	V-SMOW		-13.1	V-PDB
8	UF	3268	37227	Mammalia	Artiodactyla	Tayassuidae	Mylohyus	fossilis	dentary, left	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low left	tooth, low left	third	29.7	V-SMOW		-11.2	V-PDB
9	UF	3279	37238	Mammalia	Artiodactyla	Tayassuidae	Mylohyus	fossilis	skull, partial	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, upp left	tooth, upp left	third	29.4	V-SMOW		-11.9	V-PDB
10	UF	4051	38002	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	mandible,	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low right	tooth, low right	first	30.2	V-SMOW		-9.2	V-PDB
11	UF	7559	41496	Mammalia	Artiodactyla	Bovidae	Bison	latifrons	skull, right	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low right	tooth, low right	third	30.5	V-SMOW		-1.1	V-PDB
12	UF	8902	42866	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	maxilla, right	REDDICK 1	MR055	29.36123	-82.1856	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	third				-9.2	V-PDB
13	UF	10252	44189	Mammalia	Artiodactyla	Cervidae	Odocoileus	virginianus		HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	third	31.6	V-SMOW		-12.3	V-PDB
14	UF	10253	44190	Mammalia	Artiodactyla	Cervidae	Odocoileus		SKELETON	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low right	tooth, low right	second	29.9	V-SMOW		-14.2	V-PDB
15	UF	10324	44261	Mammalia	Artiodactyla	Tayassuidae	Mylohyus	fossilis	palate with	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	third	29.7	V-SMOW		-11.1	V-PDB
16	UF	10935	44908	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	dentary, right	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, low right	tooth, low right	first	30.4	V-SMOW		-8.7	V-PDB
17	UF	10938	44911	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	DP4, right	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	fourth	31.6	V-SMOW		-9.9	V-PDB
18	UF	11503	45440	Mammalia	Artiodactyla	Camelidae	Hemiauchenia		M3, left upper	INTRACOA	SA017	27.08221	-82.4303	Pleistocene	Rancholabre	Ra2	tooth, upp left	tooth, upp left	third				-5	V-PDB
19	UF	11503	45440	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	M3, left upper	INTRACOA	SA017	27.08221	-82.4303	Pleistocene	Rancholabre	Ra2	tooth, upp left	tooth, upp left	third				-5	V-PDB
20	UF	12494	46224	Mammalia	Artiodactyla	Tayassuidae	Mylohyus		maxilla, right	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	first	29.1	V-SMOW		-9.1	V-PDB
21	UF	16187	50124	Mammalia	Artiodactyla	Bovidae	Bison	latifrons	M1 or M2,	HAILE 8A	AL026	29.69498	-82.5824	Pleistocene	Rancholabre	Ra2	tooth, upp left	tooth, upp left	first or second	30.4	V-SMOW		-4.7	V-PDB
22	UF	17518	51483	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	maxilla, left	INGLIS 1A	CI001	29.00743	-82.6893	Pleistocene	Blancan,	le B13	tooth, upp left	tooth, upp left	fourth				-10.2	V-PDB
23	UF	17519	51484	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	maxilla, left	INGLIS 1A	CI001	29.00743	-82.6893	Pleistocene	Blancan,	le B13	tooth, upp left	tooth, upp left	none/NA				-9.1	V-PDB
24	UF	17522	51487	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	mandible,	INGLIS 1A	CI001	29.00743	-82.6893	Pleistocene	Blancan,	le B13	tooth, low right	tooth, low right	third				-12.4	V-PDB
25	UF	17693	51630	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	m3, left lower	SANTA FE	CO003	29.83699	-82.6996	Pleistocene	Blancan or	Rancholabre	tooth, low left	tooth, low left	third				-13.4	V-PDB
26	UF	18027	51964	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	right upper	INGLIS 1A	CI001	29.00743	-82.6893	Pleistocene	Blancan,	le B13	tooth, upp right	tooth, upp right	third				-11.3	V-PDB
27	UF	18028	51965	Mammalia	Artiodactyla	Camelidae	Hemiauchenia	macrocephala	M3, right upper	WITHLACC	LV041	29.01356	-82.6281	Pleistocene	Rancholabre	Ra2	tooth, upp right	tooth, upp right	third				-7.9	V-PDB
28	UF	18188	52125	Mammalia	Artiodactyla	Tayassuidae	Platygonus	bicalcaratus	MANDIBLE	INGLIS 1A	CI001	29.00743	-82.6893	Pleistocene	Blancan,	le B13	tooth, upp right	tooth, upp right	third				-11.5	V-PDB
29	UF	18196	52133	Mammalia	Artiodactyla	Tayassuidae	Platygonus	bicalcaratus	right upper	INGLIS 1A	CI001	29.00743	-82.6893	Pleistocene	Blancan,	le B13	tooth, upp right	tooth, upp right	third				-12	V-PDB

An example: Data manipulation

- Data subset by mammalian class (crocodylians not included)
- Simply plotted specimen age by $\delta^{13}\text{C}$



```
R Console
R version 3.2.4 (2016-03-10) -- "Very Secure Dishes"
Copyright (C) 2016 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> |

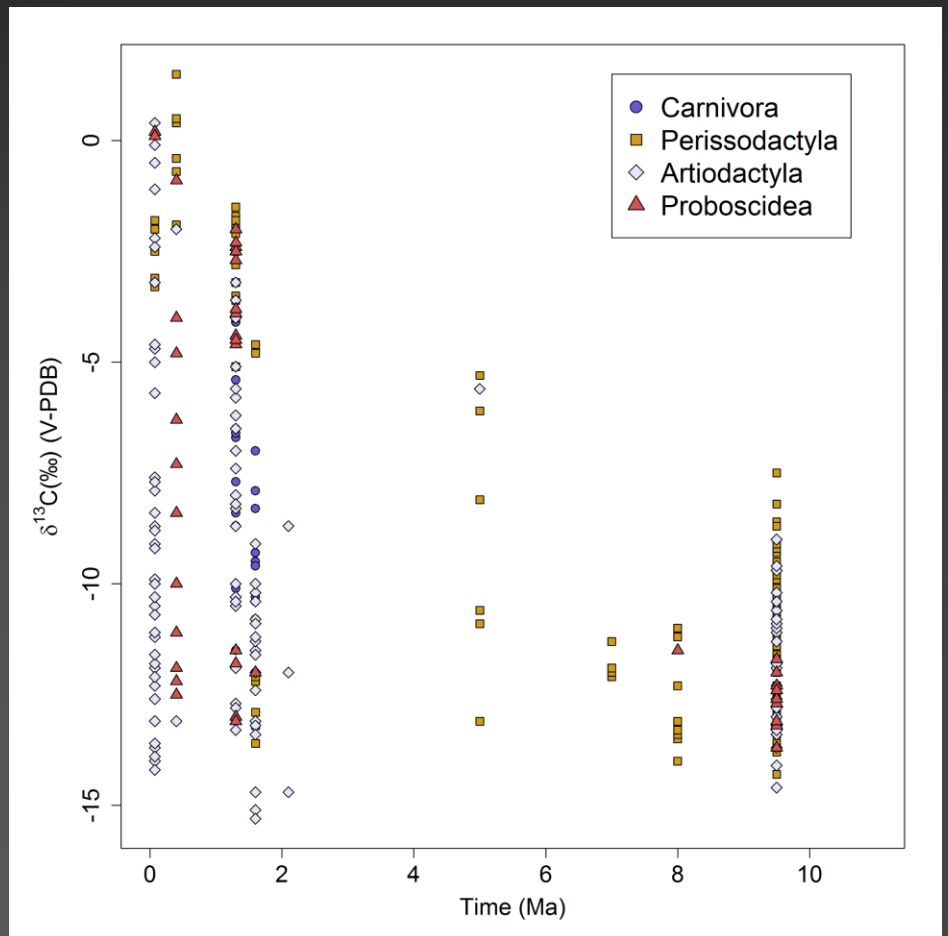
C:\R Scripts\GSA 2016 Isotope plot script.R - R Editor
###Isotope Plot for GSA 2016

isotopes<-read.csv("GSA_isotopes.csv", na.strings=NA)
Carnivora<- isotopes[isotopes$Order_Replaced=="Carnivora",]
Perissodactyla<- isotopes[isotopes$Order_Replaced=="Perissodactyla",]
Artiodactyla<- isotopes[isotopes$Order_Replaced=="Artiodactyla",]
Proboscidea<- isotopes[isotopes$Order_Replaced=="Proboscidea",]

tiff(file="GSA_carbon age plot.tiff",width=10,height=10,units="in",res=300)
par(mar=c(4,5,2,1))
par(oma=c(1,1,0,1))
plot(isotopes$Age.for.Plot, isotopes$carbon,type="n",xlab=expression(paste("Time"
points(Carnivora$Age.for.Plot,Carnivora$carbon,pch=21,bg="slateblue3",cex=1.25)
points(Perissodactyla$Age.for.Plot,Perissodactyla$carbon,pch=22,bg="goldenrod3",c
points(Artiodactyla$Age.for.Plot,Artiodactyla$carbon,pch=23,bg="lavender",cex=1.2
points(Proboscidea$Age.for.Plot,Proboscidea$carbon,pch=24,bg="indianred3",cex=1.2
legend(7,1.5,cex=1.75,pt.cex=1.75,c("Carnivora","Perissodactyla","Artiodactyla",
dev.off()|
```

An example: Expansion of C4 consumption

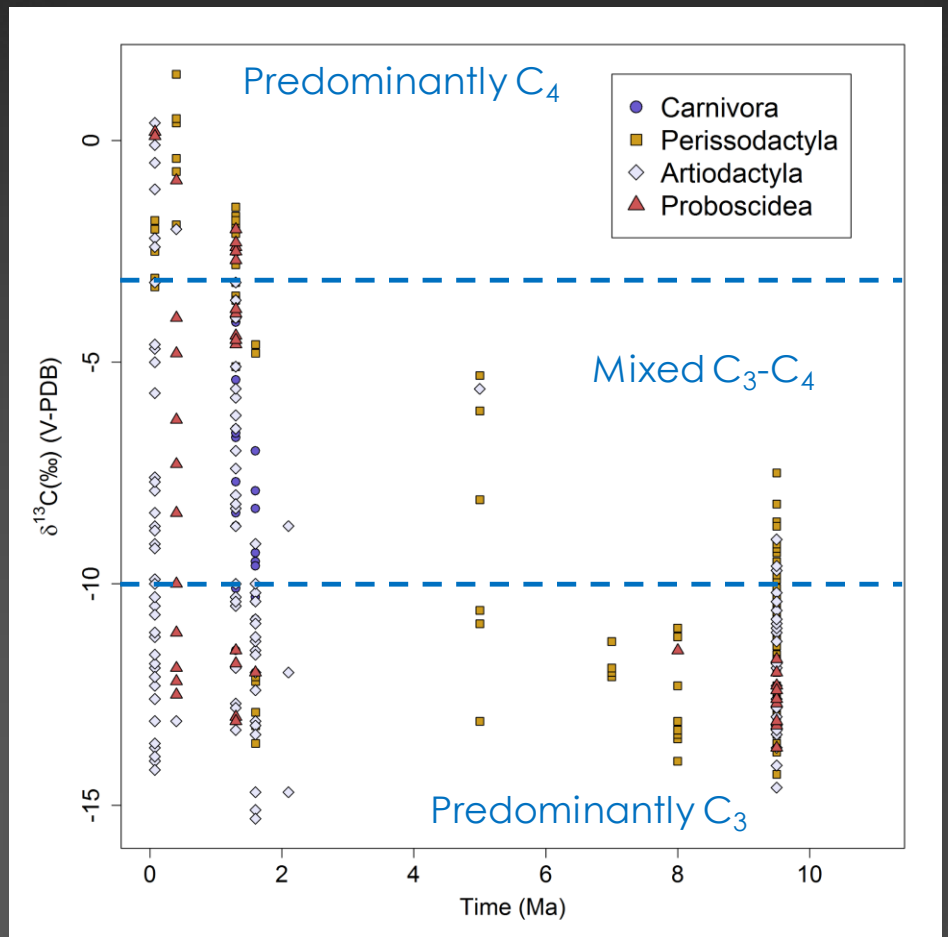
- Increase in tooth enamel carbonate $\delta^{13}\text{C}$ in Florida over last 10 Ma
- n=369



Data included from Feranec 2003, Feranec and MacFadden 1996, MacFadden 1998, MacFadden and Cerling 1996, Yann and DeSantis 2014

An example: Expansion of C4 consumption

- Increase in tooth enamel carbonate $\delta^{13}\text{C}$ in Florida over last 10 Ma
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Obstacles

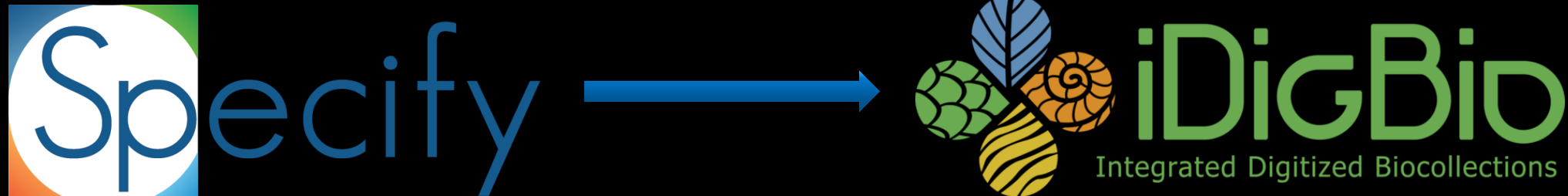
Samp. No. ¹	UF Cat. no.	Family ²	Taxon ³ (genus)	Material ⁴	Locality	$\delta^{13}\text{C}$ (‰)
93	115776	Tap	<i>Tapirus</i>	p3, ml-m $\bar{3}$	Ichetucknee	-10.1
94	19376	Bov	<i>Bison</i>	RP/M	Ichetucknee	-3.9
95	v4703	Cer	<i>Odocoileus</i>	RM2-M3	Ichetucknee	-13.8
97	None	Cam	<i>Hemiauchenia</i>	rp4	Cutler	0.4
98	None	Bov	<i>Bison</i>	LP/M	Cutler	1.5
99	None	Bov	<i>Bison</i>	lp/m	Cutler	-0.5
100	None	Tay	<i>Mylohyus</i>	rm2/m3	Cutler	-8.0
101	None	Tay	<i>Platygonus</i>	lm3	Cutler	-8.3
102A	None	Equ	<i>Equus</i>	incisor	Cutler	0.2
102B	None	Equ	<i>Equus</i>	RP3/P4	Cutler	-0.4
103	None	Equ	<i>Equus</i>	rp2	Cutler	-0.5
104	None	Equ	<i>Equus</i>	rp/m	Cutler	-0.6

MacFadden and Cerling, 1996

- Uncataloged specimens
- Incorrectly labeled specimens
- Lost specimens
- Unreported $\delta^{18}\text{O}$ data
- Data quality control
- Serially sampled specimens

Research potential and future directions

- Provides the opportunity for paleontologists to address hypotheses of the past that, until now, could only be addressed by modern ecologists.



- Necessary to develop global standards for isotope metadata (TDWG)