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SUPPLEMENTARY ONLINE MATERIAL FOR

New Miocene sulids from Peru and considerations on their Neogene fossil record in the Eastern Pacific Ocean

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Supplementary Online Material

SOM 1. Measurements (in mm) of the skull of sulid extant and extinct species. X: incomplete.

SOM 2. Measurements (in mm) of the postcranial elements of *Sula figueroae* sp. nov. MUSM 2501 (holotype) and MUSM 2502 (paratype).

SOM 3. Measurements (in mm) of the postcranial elements of sulid extant and extinct species.

References

SOM 1. Measurements (in mm) of the skull of sulid extant and extinct species. X: incomplete. *Sula variegata*: n=30, *Sula nebouxii*: n=30, *Sula dactylatra*: n=8, *Sula sula*: n=1, *Sula leucogaster*: n=2, *Sula granti*: n=4, *Papasula abbotti*: n=2, *Morus bassanus*: n=1, *Morus capensis*: n=2, *Morus serrator*: n=2. See details in Stucchi (2013).

Measurements	*R. ramirezi*	*R. aguirrei*	*S. brandi*	*S. figueroae*	*S. variegata*	*S. nebouxii*	*S. dactylatra*	*S. sula*	*S. leucogaster*	*S. granti*	*P. abbotti*	*M. bassanus*	*M. capensis*	*M. serrator*
Rostrum length	~101	104.7	x	100.2	84.3 (91.4-76.5)	93.6 (100.1-84.5)	93.2 (97-90)	71.8	88.5 (88.9-88.1)	94.1 (97-92.4)	94.5 (96.3-92.6)	111.3	96.5 (98.1-94.8)	91.3 (94.3-88.3)
Neurocranium length	68.3	75.6	60	68,4	58.7 (63.3-56.1)	62.3 (65.7-57.6)	66.6 (69.1-64.7)	54,3	59.3 (59.7-58.9)	64.8 (68.9-61.8)	67.6 (68.5-66.7)	77,1	70.8 (71.6-70)	67.7 (68.7-66.6)
Neurocranium height	33,6	33,7	23,1	27,5	26.9 (29.2-25.7)	27.5 (29.8-26.4)	28.7 (29.2-27.6)	26,8	26.1 (26.9-25.4)	28.2 (29.2-27.6)	32.8 (33.2-32.4)	34,5	34.4 (34.5-34.3)	31.9 (31.9-31.9)
Width at the level of paroccipital processes	47,7	45,4	35,1	36,7	35.2 (37.8-33.3)	38.3 (40.1-34.8)	38.7 (40.4-37.5)	31,2	33,4	38.6 (40.7-37.3)	40.4 (41.1-39.6)	49,1	42.9 (43-42.8)	44.6 (45.3-43.8)
Width at the level of the preorbital processes	~33.9	~33.9	28,8	30,9	25.7 (27.6-23.8)	27.3 (29.4-25.6)	30.8 (32.7-29.7)	26,2	27.5 (27.8-27.1)	29.1 (33.1-26.7)	29,1	33,5	29.7 (30.3-29.1)	28.8 (29.6-28)
Nasofrontal hinge width	28,7	25	24,5	24	19.8 (21.2-18.4)	20.7 (21.7-19)	23.4 (24-22.2)	20,2	21.4 (21.9-20.9)	22.3 (25.1-20.5)	27,2	25,9	22.6 (23.1-2)	22.5 (22.7-22.3)
Breadth at the exoccipitals	22,7	23,4	14,8	15,6	15 (16.8-14.2)	15.8 (17.1-14.2)	17 (18.2-16.5)	14,1	14.4 (14.5-14.2)	16.7 (17.4-16.1)	19.2 (19.4-18.9)	21,8	17.3 (17.4-17.2)	18.7 (19.3-18.1)
Breadth at the postorbital processes	50,2	~51.7	x	48,6	41.7 (44.5-39.9)	42.9 (44.7-40.8)	x	x	42.2 (42.3-41)	45.1 (50.4-41.8)	x	56,5	x	x
Postorbital process size	9,4	9,8	x	12	6.7 (8-5.3)	7.8 (9.6-6)	x	x	8 (8.9-7)	8.4 (9.6-7.4)	x	11,2	x	x
Occipital condyle width	5,5	7	4,7	5	4.4 (4.9-4)	4.8 (5.5-4)	5 (6.6-4.4)	3,7	4.4 (4.6-4.2)	5 (5.4-4.8)	5 (5-5)	6,7	5.1 (5.1-5)	5.6 (5.7-5.5)
Occipital condyle height	5	5,5	3,5	4	3.4 (3.7-3.2)	3.6 (4.2-3)	3.9 (4.4-3.8)	2,9	3.3 (3.4-3.1)	4 (4.1-3.8)	4 (4-3.9)	5,1	4.5 (4.9-4.1)	4 (4-4)
Foramen magnum width	10	10,1	8,3	6,3	9 (9.8-8.4)	9 (9.6-8.4)	9.6 (10-9.3)	8,2	8 (8.2-7.7)	9.4 (9.7-9.2)	9.4 (9.4-9.3)	10,2	9.9 (10-9.8)	9.5 (9.6-9.3)
Foramen magnum height	10	11,2	7	8,2	8.1 (8.9-7.1)	8.4 (9.2-7.7)	8.4 (8.6-8.2)	6,8	8.2 (8.4-7.9)	8.5 (8.7-8.1)	9.3 (9.3-9.2)	11,7	9.5 (9.5-9.4)	10.4 (10.6-10.2)
Quadrate width	x	19,6	x	17,8	13.3 (14.9-12.5)	14 (15-12.6)	15.5 (16.8-14.3)	14	14.5 (14.9-14.1)	15.6 (17.4-14.6)	16 (16.3-15.6)	19,2	14.1 (16.1-12.1)	14 (16.3-11.7)
Quadrate height	x	24,9	x	21,7	17.1 (18.7-15.9)	18.3 (19.4-16.4)	20 (21.1-18.5)	15,9	17.8 (18-17.5)	19.5 (20.7-18.9)	21.5 (21.6-21.3)	24	20.7 (20.9-20.4)	21.1 (21.5-20.6)
Orbital fossa size	27,1	25,7	22,8	23,2	21.6 (23.1-20.2)	21.3 (23.4-19.4)	22.2 (23.4-21.1)	18,3	21	21.9 (22.6-21.2)	25	28,2	27.5 (27.9-27.1)	25.9 (26.4-25.4)
Fossa temporalis size	11,5	13	13	14,3	11 (12.5-9)	13 (14.6-11.6)	12.1 (12.6-11.2)	11	11.7 (12.7-10.7)	12.9 (13.9-12.1)	13.6 (15-12.2)	15,8	15.2 (16.2-14.1)	14.1 (14.9-13.2)
Mandible width at the coronoid process	x	x	x	17,7	12.9 (14.4-11.2)	13.9 (14.9-12.8)	15.8 (17.1-14.8)	12,1	13.4 (13.5-13.3)	15.8 (17.4-14.6)	18.4 (18.6-18.1)	18,1	16.1 (16.3-15.9)	15.4 (15.7-15)
Breadth between the coronoid proc. and the medial mandibular proc.	x	x	x	32,5	30 (33.6-26.9)	33.5 (35.5-29)	34.4 (36.8-33.2)	25,9	30.5 (30.8-30.2)	34.3 (36.2-33.6)	33.5 (34-32.9)	41,4	34.9 (35.6-34.2)	35.3 (36-34.5)

Proportions														
Rostrum length / Neurocranium length	1,48	1,38	x	1,46	1,44	1,50	1,40	1,32	1,49	1,45	1,40	1,44	1,36	1,35
Rostrum length / Nasofrontal hinge width	3,52	4,19	x	4,18	4,26	4,52	3,98	3,55	4,14	4,22	3,47	4,30	4,27	4,06
Neurocranium length / Neurocranium height	2,03	2,24	2,60	2,49	2,18	2,27	2,32	2,03	2,27	2,30	2,06	2,23	2,06	2,12
Neurocranium length / Paroccipital processes width	1,43	1,67	1,71	1,87	1,67	1,63	1,72	1,74	1,78	1,68	1,67	1,57	1,65	1,52
Neurocranium length / Breadth at the postorbital processes	1,36	1,46	x	1,41	1,41	1,45	x	x	1,41	1,44	x	1,36	x	x
Neurocranium height / Width at the level of paroccipital processes	0,70	0,74	0,66	0,75	0,76	0,72	0,74	0,86	0,78	0,73	0,81	0,70	0,80	0,72

SOM 2. Measurements (in mm) of the postcranial elements of *Sula figueroae* sp. nov. MUSM 2501 (holotype) and MUSM 2502 (paratype).

		MUSM 2501 (holotype)		MUSM 2502 (paratype)	
		Left	Right	Left	Right
Humerus	Total length	x	x	186,5	185,6
	Proximal width	30,9	x	29,3	28,4
	Distal width	24,9	24,9	23,8	24,3
	Mid-shaft maximum width	x	11,3	10,8	10,6
Carpometacarpus	Proximal width	20,4	x	x	x
	Distal width	12,7	x	x	x
Femur	Proximal width	x	x	x	15,2
	Distal width	x	x	x	16,8
Tibiotarsus	Distal width	x	x	x	14,2
Tarsometatarsus	Antero-posterior proximal width	x	x	x	14,3
	Latero-medial proximal width	x	x	x	14,8
Coracoides	Total length	x	x	73,3	73,8
	Sternal facet length	x	x	16,7	15,9
	Head length	x	x		14,4
	Glenoid facet length	x	x	13,6	13,1
	Distance head-glenoid facet	x	x	26,3	26,7
Scapula	Total length	x	x	88,7	x
	Proximal width	x	18,9	20,7	x
Sternon	Total length	x		109,3	
	Breadth at the sternocoracoid processes	x		63,3	
Pelvis	Total length	x		116,7	
	Breadth at the antitrochanteric processes	48,7		47	
Ulna	Proximal width	21,8	x	x	16,2

SOM 3. Measurements (in mm) of the postcranial elements of sulid extant and extinct species. Fossil taxa measurements are shown in original descriptions unless those indicated by a letter. A: Wetmore (1938); B: USNM 177935; C: USNM 23721; D: USNM 412010; E: Brodkorb (1955); F: USNM 412070; G: USNM 411963; H: USNM 426031; I: USNM 193364; J: USNM 252310; K: Grigorescu and Kessler (1977); L: USNM 178033; M: USNM: 501511; N: Howard (1978); O: USNM 215722; P: USNM 426057; Q: USNM 181029; R: USNM 215761; S: Miller (1935); T: Chandler (1990); U: USNM 501514; V: USNM 215716; W: USNM 411981; Y: Olson and Rassmussen (2001); Z: USNM 412017; AA: USNM 426023; BB: USNM 426061; CC: USNM 177910; DD: USNM 412054; EE: USNM 367093. *Sula variegata* and *S. nebouxii* are after Stucchi (2003); *S. leucogaster* and *S. sula* are the mean from Warheit (1992); *S. dactylatra* and *S. tasmani* from Tets et al. (1988); *Sula* indet. sensu Stucchi (2003). (*) Sula indet. from Pisco Formation (Stucchi 2003).

Sulid species	Humerus				Ulna		Carpometacarpus	Tarsometatarsus	Femur	Tibiotarsus	Coracoid
	Total length	Proximal width	Distal width	Mid-shaft maximum width	Total length	Proximal width	Total length	Total length	Total length	Total length	Total length
Sarmatosula dobrogensis	158	x	x	x	127	x	x	50	x	110	x
Morus loxostylus	x	x	21.1A	x	x	13.1B	70.6C	55.6D	x	x	51.3/48.2E
Morus atlanticus	166.5F	22.5F	17.6G /17.5F	x	146.2F	12.2H / 12.8F	71I / 69.6F	49F	57.6J / 50F	80.1F	x
Morus vagabundus	170K	x	18,3	x	x	x	x	x	x	x	x
Morus avitus	x	x	15.3L /15.2	x	x	9.7M	75N /65 /56.3O	52.7P / 48.7Q	52.9R	x	x
Morus pygmaea	128K	x	x	x	x	x	x	x	x	x	x
Morus olsoni	x	x	x	x	x	x	70,2	x	x	x	x
Morus willetti	156	x	x	x	147	x	70	41	52	71	45
Morus stocktoni	264	x	x	x	175	x	102	x	x	x	x
Morus lompocanus	245 / 230S	28	x	x	201S / 107.6T	x	96.6N / 95.7N / 94.7N	x	69	x	62
Morus magnus	x	x	29,2	x	x	x	116,1	x	x	x	x
Morus media	181S / 180	x	x	x	140	x	81	64	x	x	x
Morus peninsularis	x	26.6U	22V / 22W / 21Y	x	x	15.1Z	78.8AA	57.5BB	59.1CC	x	64.2EE/ 59.8DD/55.6-54
Morus humeralis	x	28T	19.8 /19.7T	x	x	14.7T	x	x	58.2T	x	x
Morus recentior	x	x	x	x	248.3T	18.2T	x	x	x	114	64.7T
Morus reyanus	x	x	x	x	x	x	x	x	x	x	56,6
Morus peruvianus	x	x	x	x	165	14,8	76,8	x	x	x	x
Sula pohli	150.5-145	22,1	17,3	x	170-148.5	x	69,3	x	x	x	55
Sula tasmani	209 (210-206)	30	23 (23-21)	11-9.0	212 (216-208)	17 (18-16)	92	64 (65-62)	68 (70-67)	100	75
Sula magna	251.5-245	38.5-34.5	30.2-28	13.7 (14-	271	21.5-19.6	123.9-115.2	x	x	x	93-91

				13.4)							
Sula sulita	x	x	15,8	x	x	x	x	x	x	x	45,7
Sula aff. variegata	x	x	20	x	x	15.5-13	x	x	x	x	x
Sula indet. (*)	240-210	34.2-29.1	27.8-21.8	x	247-230	19.1-17	113.7-101.9	73.2-62.5	75-68.5	x	88.1-74.1
Sula figueroae	191-185	30.9 -28.4	25-24.4	11.3-10.6	x	16,2	92,9	58,8	72,8	98,1	73,3
Sula dactylatra	193 (202-186)	29 (30-28)	20 (21-19)	9.1-7.8	204 (211-196)	15 (15-14)	86 (90-85)	60 (63-57)	64 (66-61)	95	68 (73-67)
Sula leucogaster	156,3	22,7	18,3	x	169,2	12,5	73,5	46,7	50,4	76,3	51,9
Sula nebouxii	182.35 (195.5-161.5)	24.92 (26.3-22.5)	19.74 (20.72-18.14)	8.82 (9.9-7.8)	210-172	14.5-12.1	85.8-70.9	57.6-49.8	56.7-49.6	93.4-79.9	55.5-47.7
Sula variegata	161.94 (175-161)	23.27 (25.6-21.3)	18.3 (19.8-17.2)	8.45 (9-7.7)	186.3-158.5	14.3-11.9	78.6-69.4	52.8-45.6	56.8-49.7	90.9-81.1	55.3-48.2
Sula sula	161,5	22,3	18,3	x	181,2	12,9	71,6	36,2	48	65,9	47,2

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