THE FIRST RECORD OF *OSBORNODON* (CARNIVORA: CANIDAE) FROM THE ORELLAN OF SOUTH DAKOTA

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ABSTRACT

During the 2013 summer season, a visitor at Badlands National Park discovered an *in situ* fossil dog skull, and reported the location to park rangers, following in correspondence with the park's Visitor Site Report program. The skull was fortuitously left at its locality so the contextual data could be properly collected. The discovery came from a fairly fossiliferous limestone in the upper Scenic Member of the Brule Formation, Jackson County, South Dakota. Unofficially known as the Abbey mudstone, this unit lies within the *Merycoidodon bullatus* zone and is thus within the fourth and latest subdivision of the Orellan North American Land Mammal Age. After preparation, the specimen was identified as the rare hesperocyonine canid, *Osbornodon renjiei*. This diagnosis is based primarily on the elongated molars and a ridged entoconid forming a basined talonid on the m1. This specimen of *O. renjiei* possesses the most complete dentition of any specimen yet reported in the literature. Previously known occurrences of *O. renjiei* comprise four specimens from the Orellan of North Dakota, a single Whitneyan occurrence in Nebraska, and two specimens, previously attributed to the closely related taxon *Cynodictis* (synonymized with "*Mesocyon*") *temnodon* in the Whitneyan "*Protoceras* channels" of South Dakota. The Badlands National Park specimen herein represents a new stratigraphic record in South Dakota, contributing a new faunal constituent to the local Late Orellan fauna as well as further understanding of the biochronology of the South Dakota Big Badlands paleobiogeographic region.

Keywords

Badlands, Brule, Canidae, Orellan, Osbornodon

INTRODUCTION

The White River Badlands of the Great Plains are some of the richest fossil bearing units in North America. Significant paleontological discoveries have been made in South Dakota since the mid-1800's and continue today (e.g. Leidy 1856; Boyd and Welsh 2014). The unique geology and rich fossil resources were

major justifications for the establishment of Badlands National Monument in 1939 and accession of the South Unit for Badlands National Park in 1978. Badlands National Park has received around 900,000 visitors annually since 2005. Many of these visitors exercise the park's open hiking policy, which facilitates nearly complete access to all areas within the park. This policy results in visitors directly interacting with geologic and paleontological resources. Because of this, the Visitor Site Report (VSR) program was established. VSR's are an invaluable resource to educate the public on how fossil resources are managed in the park as well as to provide opportunities for visitor participation in the science through discovery. These VSRs have resulted in several significant fossil discoveries in the park, and has proved to be a vital tool in the management of fossil resources.

One particular VSR from the early part of the summer 2013 visitor season resulted in the collection of a small caniform carnivore skull within the upper portion of the Scenic Member, Brule Formation. On-site inspection showed that the skull was too large for *Hesperocyon*, but also too small for the next most common caniform, *Daphoenus* (Amphicyonidae). Significance was evaluated on the potential of this specimen being a poorly known canid, such as *Mesocyon*, or a small amphicyonid, exemplified by *Daphoenictus* or *Paradaphoenus*. The fossil was found as float in a frequently visited area, so the threat of potentially destructive impact or theft provided further justification to collect. After collection and subsequent preparation at the on-site preparation laboratory, the specimen was identified as a new geographic and stratigraphic occurrence of the rare canid *Osbornodon renjiei*.

Previous taxonomic understandings of White River Group Canidae has been somewhat convoluted, particularly with *Hesperocyon* (*see* Wang 1994). Recent studies, grounded in modern techniques, of fossil and modern canids have provided major resolution to historically confusing taxonomy (Wang 1994; Wang et al. 1999; Tedford et al. 2009).

The oldest occurrence of canids begins with *Hesperocyon gregarius* in the mid-Duchesnian Lac Pelletier Lower Fauna, Cypress Hills Formation, Saskatchewan (Bryant 1992). Though Wang (1994) refers to *Prohesperocyon* as the only co-occurring canid with *H. gregarius* in the Chadronian, and possible progenitor to Canidae, later phylogenetic analysis placed *Prohesperocyon* within the Miacidae (Wesley-Hunt and Flynn 2005; Wesley-Hunt and Werdelin 2005). Hesperocyonines diversified slightly through the Orellan and Whitneyan, but *H. gregarius* remains the dominant canid component of the White River Chronofauna (Wang 1994). Three subfamilies occur throughout the White River Chronofauna: Hesperocyoninae, Borophaginae, and Caninae. Borophagines and canines are collectively known from only three specimens in correlative units containing Orellan faunas (Wang et al. 1999; Tedford et al. 2009). Hesperocyonines greatly diversified throughout the Arikareean, then were reduced to extinction in the early Barstovian (Wang 1994). The Borophaginae appeared in the Orellan, diversified dramatically in the Arikareean and throughout the Miocene until their extinction in the Blancan (Wang et al. 1999). The third subfamily, the Caninae, with the only White River Group occurrence in the Orellan, held a low diversity through the rest of the Oligocene and Early Miocene, followed by increasing

diversification starting at the Middle Miocene and continuing into the Recent (Tedford et al. 2009).

In the Scenic Member of the Brule Formation of South Dakota, typically attributed to Orellan faunas, the canid record is dominated by *Hesperocyon*. Several hundred specimens found throughout the Great Plains region are held in various museum collections (see Appendix I in Wang 1994). Occurrences of other canids during this lithologic interval and biostratigraphic zonation in South Dakota are limited to a single occurrence of another hesperocyonine, "*Mesocyon*" *temnodon* (SDSM 2653). Elsewhere, in coeval sites, non-*Hesperocyon* specimens are still limited to a partial dentary of the canine *Leptocyon* from Nebraska, four specimens of *Osbornodon renjiei* from North Dakota, and thirteen specimens of "*Hesperocyon*" *coloradensis* from Colorado (Tedford et al. 2009; Wang 1994). Any additional information into the early diversification and dispersals of canids would be beneficial, given the limited diversity previously recorded.

GEOLOGIC AND BIOCHRONOLOGIC SETTING

The specimen described herein originated in the upper Scenic Member of the Brule Formation, preserved in a carbonate nodule from the informally designated Abbey mudstones in the upper-middle Scenic sandstone interval (Figure 1A; Evanoff et al. 2010).

Another locality, also situated in the Abbey mudstones, provides further insight on biostratigraphic zonation. BADL-LOC-00593, also known as the "Saber-site", has produced a multitaxic fauna of the Late Orellan. Although most taxa recovered have somewhat expansive ranges in the White River Group, the presence of *Merycoidodon bullatus* (BADL 16877; Artiodactyla: Merycoidodontidae) and a yet to be determined species *Ischyromys* (BADL 59711; Rodentia: Ischyromidae) mark the fourth and latest Orellan subdivision. The "*Merycoidodon bullatus*" zone (Prothero and Emry 2004), or Or4 (Janis et al. 2008), is characterized by the first appearance of *M. bullatus* and the last appearance of *Ischyromys*, specifically *I. typus* (Prothero and Emry 2004). However, Heaton (1993) and Simpson (1985) collectively identify 5 specimens of *Ischyromys* from the lowermost Poleslide and Whitney members of South Dakota and Nebraska, which are typically associated with Whitneyan faunas. These Whitneyan occurrences of *Ischyromys* were not recognized in succeeding publications characterizing biostratigraphic subdivisions (Prothero and Whitlessey 1998; Prothero and Emry 2004). The Whitneyan occurrences were not explicitly invalidated by Prothero and Whitlessey (1998), but Anderson (2008) recognizes early and late Whitneyan occurrences of the genus. Considering that *Ischyromys* likely occurs in the Whitneyan, a Whitneyan fauna has yet to be confirmed within any horizon within the Scenic Member. Though the biochronologic assessment is tentative and requires further biostratigraphic study, it is most likely that this new record of *Osbornodon* is within the "*Merycoidodon*" *bullatus* zone (Or4).

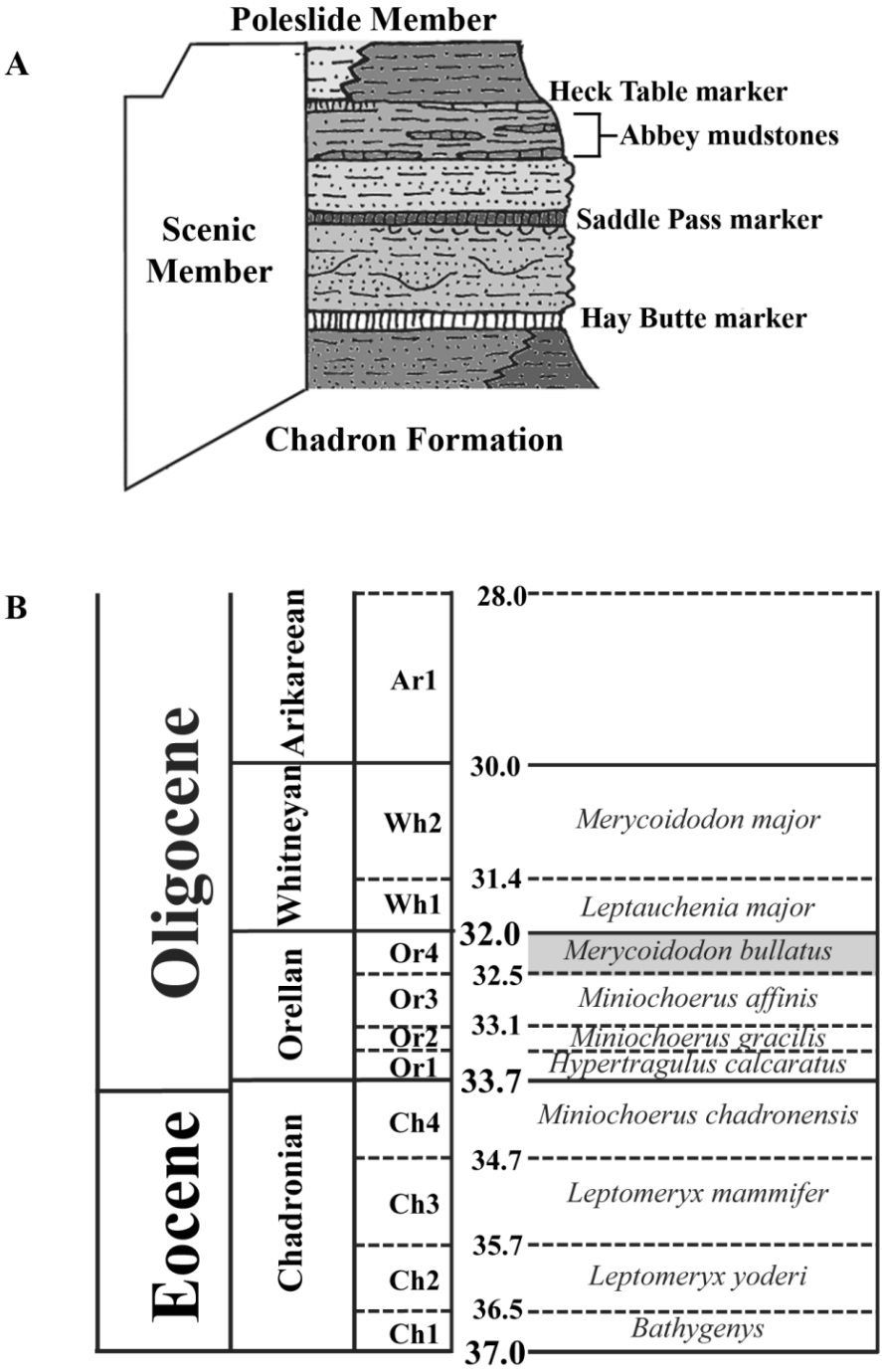

Figure 1. Diagram displaying the stratigraphic (A; modified from Evanoff et al, 2010) and biostratigraphic (B) zones of BADL 63382.

INSTITUTIONAL ABBREVIATIONS

AMNH, American Museum of Natural History; F:AM, Frick collection, American Museum of Natural History; BADL, Badlands National Park; SDSM, South Dakota School of Mines and Technology Museum of Geology.

SYSTEMATIC PALEONTOLOGY

Class MAMMALIA Linnaeus 1785
Order CARNIVORA Bowdich 1821
Suborder CANIFORMIA Kretzoi 1943
Family CANIDAE Gray 1821
Subfamily HESPEROCYONINAE Tedford 1978
Osbornodon Wang 1994
Osbornodon renjiei Wang 1994
?*Cynodictis* sp. maj. Matthew 1899: 54 (AMNH 1382 and 1386)
?*Cynodictis temnodon* Wortman and Matthew 1899: 130 (in part as above)
Cynodictis temnodon (Wortman and Matthew) Matthew 1901: 370 (in part as above)
Procynodictis temnodon (Wortman and Matthew) Matthew 1918: 189 (in part as above)
Pseudocynodictis sp. Hough 1948a: 97
Osbornodon renjiei Wang 1994: 114
Osbornodon renjiei Wang and Tedford 1996: 441

Referred Specimen—BADL 63382, slightly crushed anterior portion of skull with complete upper dentition excluding the right P1, left and right dentaries with complete lower dentition excluding the incisors and left p1 (Table 1, Figure 2).

Locality and Horizon—North Unit Badlands National Park, Jackson County, South Dakota (Figure 3). Abbey Mudstone, Scenic Member, Brule Formation, White River Group (Orellan). Specific site information is protected under federal law. Researchers who have an appropriate purpose to inquire further should contact the on-staff Paleontologist at Badlands National Park.

Description—The skull of BADL 63382 is slightly crushed, showing no distortion. The most diagnostic features of *Osbornodon* are in the basicranial region, but part of the cranium is missing in BADL 63382. However, taxonomic assessment is possible due to the specimen's near complete dentition. Two of the distinguishing synapomorphies of *Osbornodon*, provided by Wang (1994), are present in this specimen: 1) The molars are more quadrate and the M2/m2 are enlarged just slightly more than what is observed in *Mesocyon*; 2) the talonids of m1-m2 are basined.

The fracturing of the skull makes it difficult to determine the profile of the premaxilla, maxilla, and frontals. It is also difficult to gauge frontal inflation, if any. However, the muzzle is not elongated as in more derived species of *Osbornodon* and more similar to basal Hesperocyoninae, such as *Hesperocyon* (see Wang 1994). This character is also shared with *O. sesnoni* (Wang 1994). The

infraorbital foramina are also primitively rounded, as is also observed in *O. sesnoni* (Wang 1994).

BADL 63382 is the only described specimen of *Osbornodon* with incisors preserved. Both I1-2 have central cusps with two lateral accessory cusps. I3 is much larger than the other incisors, with a medial accessory cusp; there is a bridge on the posterior margin of the I3 with a slight bulge along the base of the bridge,

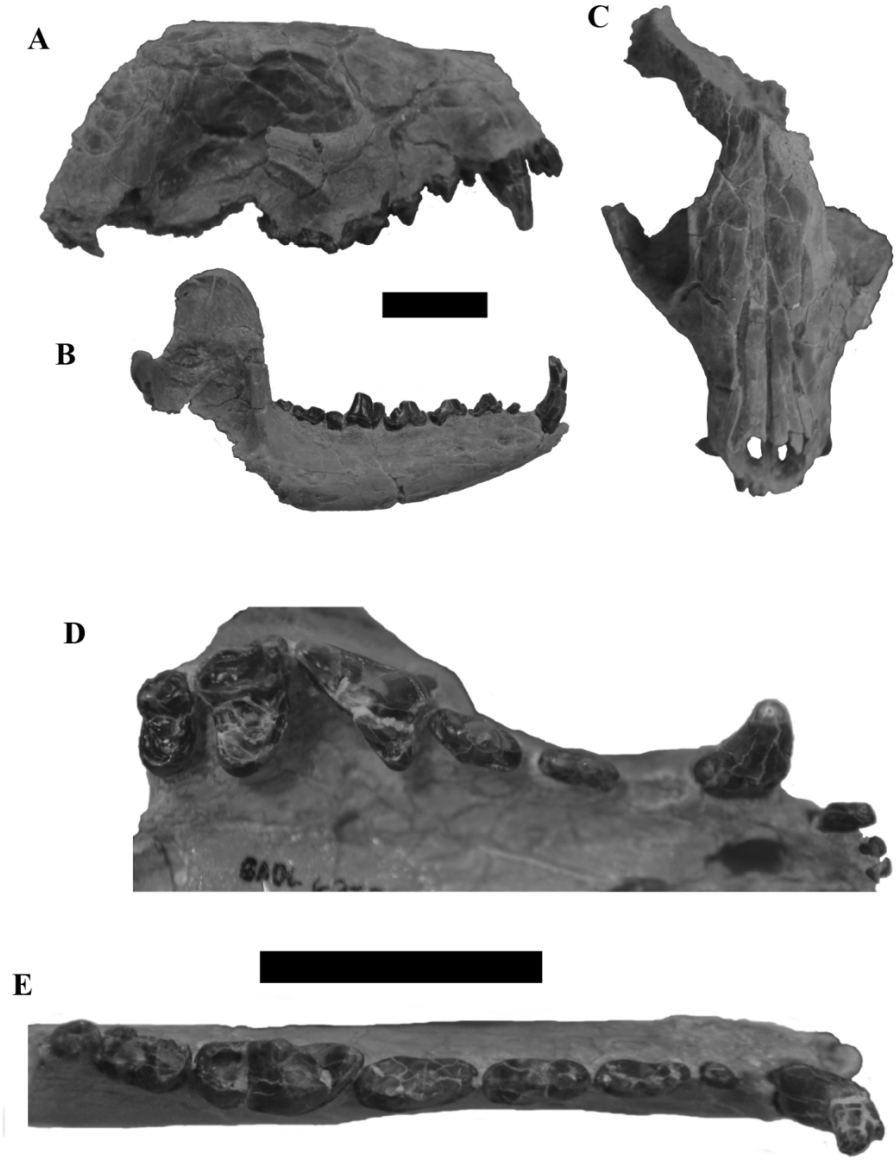

Figure 2. Views of BADL 63382: Skull in right lateral view (A); dentary in right lateral view (B); skull in dorsal view (C); right maxillary tooth row in occlusal view (D); right dentary tooth row in occlusal view (E). Scale bars equal 2 cm.

Table 1. Measurements of BADL 63382 (all measurements are in mm).

	I1	I2	I3	C	P1	P2	P3	P4	M1	M2
Length	2.09	2.18	2.45	6.44	3.4	6.4	7.66	10.78	7.93	4.68
Width	1.2	1.34	3.22	4.16	2.1	2.5	3.68	7.59	11.37	8.2
			Height=13.48							

	i1	i2	i3	c	p1	p2	p3	p4	m1
Length	N/A	N/A	N/A	5.9	2.69	6.57	7.55	8.53	11.7
Width	N/A	N/A	N/A	4.2	1.88	2.94	3.31	3.81	5.19
			Height=12.41						

m1 tgd	m1 tld	m2	m2 tgd	m2 tld	m3	m3 tgd	m3 tld
6.81	4.51	6.6	3.3	3.54	3.4	1.65	1.55
5.41	4.74	3.95	3.9	3.77	2.84	2.62	2.59

Length at Nasals	48.93	Depth of ramus at m1	15.52
Width at infraorbital foramen	27.86	Depth of ramus at m2	16.27
Depth of jugal at the orbit	9.83	Depth at angular process	48.8
Width at frontal process	28.76	Width of coronoid	17.15
Length C-M2	49.26	Diamter of the orbit (dorso-ventral)	19.65
Length I-M2	57.94	Length of incisors to anterior orbit	42.89
Length c-m2	51.88	Width across C's	22.7
Length c-m3	56.16	Width across I's	13.32
		Width across upper carnassials	39.57

but no noticeable presence of a lingual cuspule. C is somewhat conical with anteromedial and posterior ridges. P1 is single rooted and cusped. P2 and P3 contain an incipient posterior cusp on the cingulum. The P4 has a large and anteriorly positioned protocone, comparable to what has been observed in Orellan specimens of *O. renjiei* from North Dakota and unlike Whitneyan occurrences of the species (Wang 1994). The molars are antero-posteriorly lengthened, particularly along the margin of the protocone to metaconule, and have become more quadrate with a wider trigon on the M1. The M2 is slightly larger than what has been measured in "*Mesocyon*" *temnodon*.

The lower canine contains anterior and posterior ridges that are directed medially. The p1 is simple and single rooted. The p2 has anterior and posterior cingular cusps. The p3 has a vague posterior accessory cusp, more similar to what has been observed in F:AM 63963 (see Wang 1994). The p4 has a well-developed posterior accessory cusp. The m1 trigonid possesses a basined talonid, which is formed from a ridged entoconid. The entoconid rises to the height of the hypoconid. The hypoconid is notably larger than the entoconid, as is characterized in other hesperocyonine canids. The m1 hypoconid is also moderately

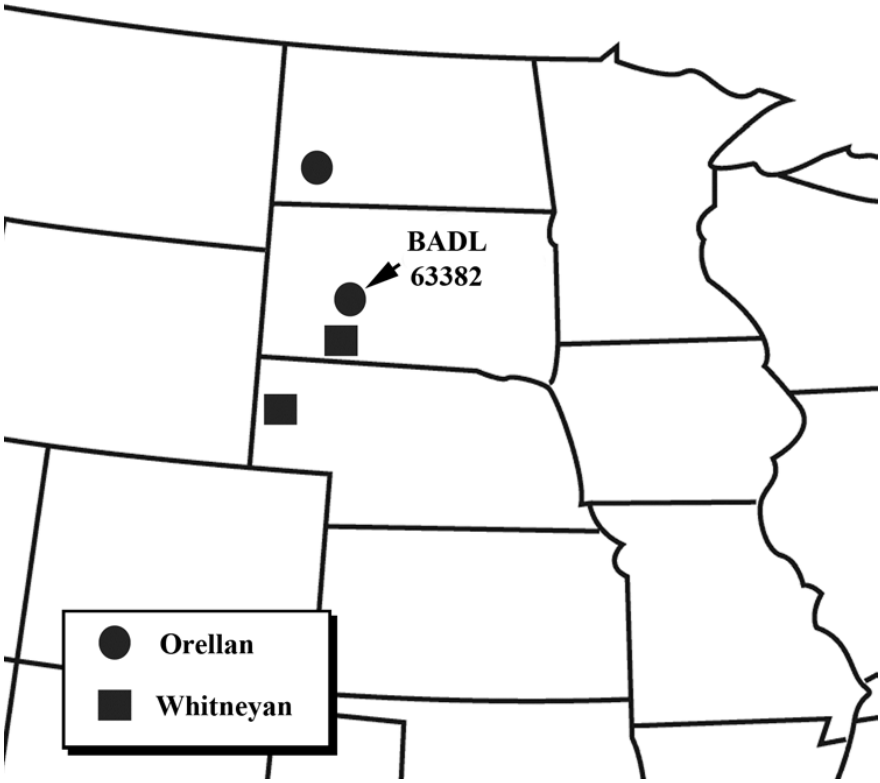

Figure 3. The known occurrences of Osbornodon renjiei, with legend marking biostratigraphic occurrences. New occurrence from this report (BADL 63382) is marked above. It should also be noted that the known occurrences of O. sesnoni are within the same vicinity as the Whitneyan occurrence of O. renjiei in South Dakota.

worn, suggesting that the hypoconid was originally slightly taller than the entoconid. This differs from borophagines and canines, which have cuspate entoconid enlarged to matching size of the hypoconid, and a transverse ridge between the hypoconid and entoconid, forming a basined talonid. The m2 contains an anteriorly positioned protoconid-metaconid ridge with a reduced paraconid. The m3 still retains the protoconid and metaconid with a faint transverse ridge between the two. The m3 trigonid is missing the paraconid, and only contains an anterior ridge. The m3 talonid is enlarged, relative to a reduced trigonid.

CONCLUSION

BADL 63382 represents a new occurrence of *Osbornodon renjiei* in the Latest Orellan "*Merycoidodon bullatus* zone" (Or4) of South Dakota, supported by a correlative fauna in the same lithologic unit. This study serves as a report of a new record which happens to adhere to the current biostratigraphic and biogeo-

graphic information provided by Wang (1994). This new record demonstrates a slightly wider biogeographic range during the Latest Orellan, before its subsequent dispersal further south in the Great Plains.

Osbornodon is the longest lived genera within the Hesperocyoninae, spanning approximately 18 million years from the Late Orellan to the Early Barstovian. This would also be true within the Canidae, with the exception of the Orellan to Clarendonian range (~29 million years) of the canine *Leptocyon* (Tedford et al. 2009). The record of *Osbornodon* begins with *O. renjiei* from the late Orellan Fitterer Ranch Locality of North Dakota (Wang 1994). The current record extends the Orellan range of *O. renjiei* in South Dakota. *Osbornodon renjiei* and *O. sesnoni* have been defined in Whitneyan localities in South Dakota and Nebraska, inferring the earliest emigration and diversification of *Osbornodon* (Wang 1994). Both species disappeared in the Whitneyan, in near correspondence with the overturn of most components of the White River Chronofauna of the Whitneyan-Arikareean transition. There is a brief apparent absence of *Osbornodon* in the Early early Arikareean (Tedford et al. 2004; [Ar1] Janis et al. 2008), then a sudden appearance of *O. wangi* from the middle of the Late early Arikareean (Tedford et al. 2004; [Ar2] Janis et al. 2008) Brooksville 2 Local Fauna, Florida (Hayes 2000). There is a near 8 million year hiatus of the taxon's fossil record from the Late early Arikareean until the genus reappears in the Late Arikareean with *O. iamonensis* and *O. brachypus* from Nebraska and Wyoming respectively, with *O. iamonensis* continuing into the Hemingfordian while extending its range to Florida. Dispersal and diversity continue with *O. scitulus* in the Early Hemingfordian of Nebraska, Texas, and Florida (Wang 2003). The last occurrence of the genus, *O. fricki*, is from Early Barstovian sites in Nebraska, California, and New Mexico (Wang 1994).

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