Swiss J Palaeontol (2013) 132:221–238
DOI 10.1007/s13358-013-0057-z

A new method to determine volume of bromalites: morphometrics of Lower Permian (Archer City Formation) heteropolar bromalites

Christen D. Shelton

Received: 12 February 2013 / Accepted: 4 July 2013 / Published online: 14 August 2013

Abstract Lower Permian vertebrates from both terrestrial and aquatic organisms have been collected from Archer County, Texas, for over a century. These include preserved shark cartilage and spiral bromalites presumed to have been produced by freshwater sharks of the genus *Orthacanthus*. Specimens were collected in the newly named Archer City Bonebed V occurring in the Archer City Formation. Physical characteristics (length, width, height, mass, eccentricity, volume, and density) were measured and recorded for 300 spiral bromalites and compared by linear regression analysis. The spiral bromalites had an average length of 31.74 mm; width 14.43 mm; height 10.51 mm, and mass 7.971 g. Eccentricity ranged from 0.9 to 0.06. All of these values follow a normal distribution. In addition to the collection of this statistical data, a new formula is proposed to help determine the volume of these elliptical fossils when volume determination by water displacement is not an option. The percent difference between the observed volumes obtained by water displacement and calculated volumes ranged from 0.04 to 56 %. Ninety-five percent of the statistical sample had a percentage difference of <30. This data, if compiled with data from the analysis of specimens from other localities, may ultimately reveal size groupings that could reflect the presence of previously unknown taxa that possessed a spiral valve and coexisted with the *Orthacanthus* sharks.

C. D. Shelton
Biology Department, Midwestern State University,
76308 Wichita Falls, TX, USA

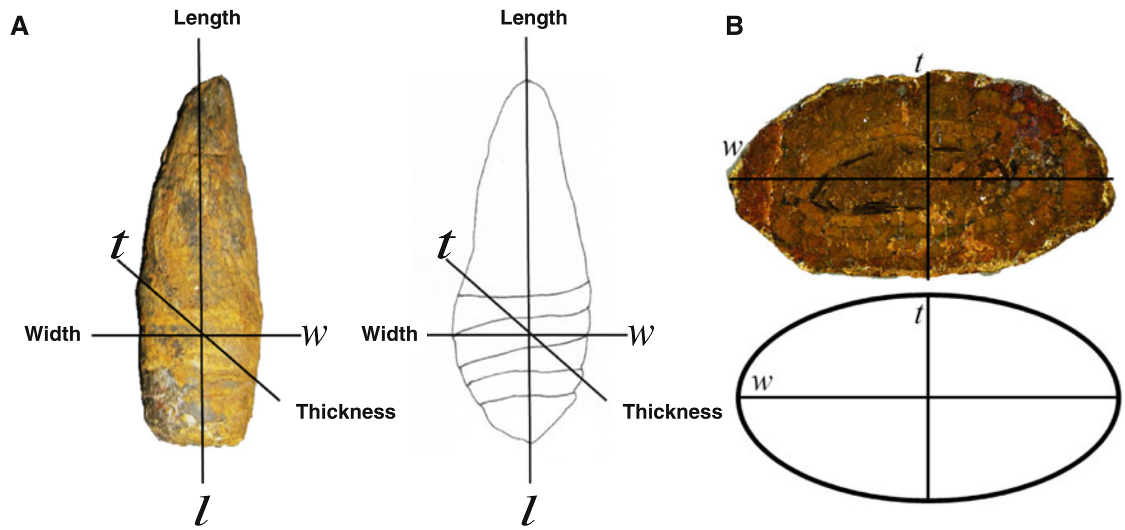
Present Address:
C. D. Shelton (✉)
Steinmann Institute, Division of Paleontology,
University of Bonn, 53115 Bonn, Germany
e-mail: cshelton@uni-bonn.de

Keywords *Orthacanthus* · Spiral coprolite · Texas · Amphipolar

Introduction

Classically, the term "coprolite" has been applied to any type of fossilized digestive material, regardless of its origin, since Rev. William Buckland coined the term in 1829. Hunt (1992) has proposed the term "bromalite" as an alternative to using the word coprolite. Bromalite means "food stone" and is defined as any fossilized digestive matter originating from animals. This encompasses true coprolites, cololites, regurgitalites, and gastrolites (Hunt 1992; Northwood 2005; Hunt et al. 2012), which are present in sedimentary rocks formed in aquatic and terrestrial environments (Amstutz 1958; Häntzschel et al. 1968; Thulborn 1991). This term has been chosen because of the controversy surrounding the true origin of spiral bromalites and to circumvent the terminology associated with these differing hypotheses about these fossils. Many authors have debated whether or not they were preserved after being expelled from the body as feces, or if they were actually retained in the body after death either in the colon or being the actual preserved spiral valve itself (Fritsch 1907; Williams 1972; Stewart 1978; Duffin 1979; Jain 1983; McAllister 1985, 1987; Chin 1996; Holmgren et al. 1999). As observed, fecal pellets from fish tend to unwind as ribbons, and dissipate into the water within hours of expulsion (Jain 1983; McAllister 1985). With the exception of the true coprolite hypothesis, each spiral bromalite would represent a death (Stewart 1978), and retention of the bromalite in the body could provide an ideal taphonomic situation for preservation.

Williams (1972) compared the length to width ratio of 38 spiral bromalites from Kansas and found a 2:1 ratio. He suggested this could be misleading due to the crushing or



$$V=\int_0^l \pi\left(\frac{w}{2l}\right)x\left(\frac{t}{2l}\right)x\,dx=\left(\frac{\pi lwt}{12}\right)\left(\frac{1}{1000}\right)=\frac{\pi(lwt)}{12{,}000}(1.7088)$$

$$e=\sqrt{1-\left(\frac{t^2}{w^2}\right)}$$

Fig. 1 The measurements taken from each of the 300 spiral bromalites and how they were used in the calculation of the volume and eccentricity. **a** Physical measurements (*l* length, *t* thickness, *w* width) taken from the spiral bromalites and used as variables in the proposed volume formula. The constant 1.7088 was found as a slope after regressing the preliminary volumes and the observed water displacement volumes. Orientation is based on Hunt and Lucas (2012). **b** Spiral heteropolar bromalite shown in cross-section indicating the measurements (*t* thickness, *w* width) used to calculate eccentricity in the formula below. The closer the value is to 1 the more crushed the specimen is

deformation of the specimens. Williams (1972) suggested that a comparison to uncrushed spiral bromalites from Texas could reveal the length to width ratio is closer to 2.5:1. If one observes the eccentricity of the cross section of spiral bromalites, an appreciation of what Williams (1972) referred to as the "crushing" can be better understood (Fig. 1b). In general, the few studies that have mentioned "coprolite" or bromalite morphometrics have only focused on a small sample or a single specimen and even then only giving a few physical aspects of the specimen(s). This is the first study to focus on what can be learned from the analysis of a larger sampling size when taking morphometrics into account. This study derives a new formula for calculating the volume of spiral bromalites by incorporating three linear measurements from each of the specimens (Fig. 1a). This formula has the potential for use when volume measurement by water displacement is not a viable option for reasons such as time constraints, quick field analysis, samples encased in matrix, calculating volume from published information without having the specimen, or the specimen may be too large or too fragile to submerge. The latter might apply to more recent Pleistocene cave deposits or bromalites from archeological sites, if this formula proves applicable to these areas of research.

It should be noted that a recent attempt has been made to categorize spiral bromalites of Permian and Triassic age by assigning them ichnotaxonomic nomenclature based on their

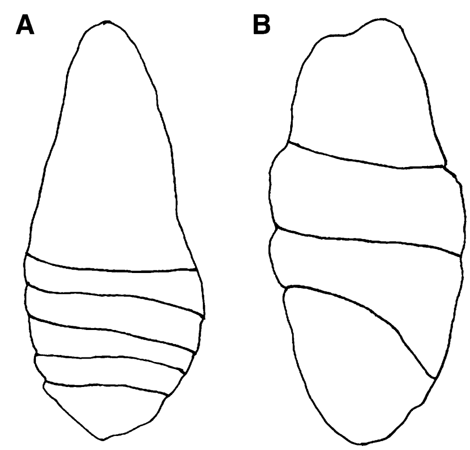


Fig. 2 **a** Spiral heteropolar bromalite morphololgy, relatively closely spaced turns concentrated towards one end. **b** Spiral amphipolar bromalite morphology, blunt ends with wider and regularly spaced turns running along the entire length (*redrawn* from Hunt et al. 1994). Orientation is based on Hunt and Lucas (2012)

morphologies, related geographical origin, and unsubstantiated hypothesized producers (Hunt and Lucas 2005a, b; Hunt et al. 1998, 2005a, b, 2007). This study does not follow this scheme to avoid adding confusion stemming from the current debate over their origin. Instead, Neumayer's (1904) bimorphological scheme for identifying spiral bromalites will suffice (Fig. 2). His classification of spiral bromalites, collected

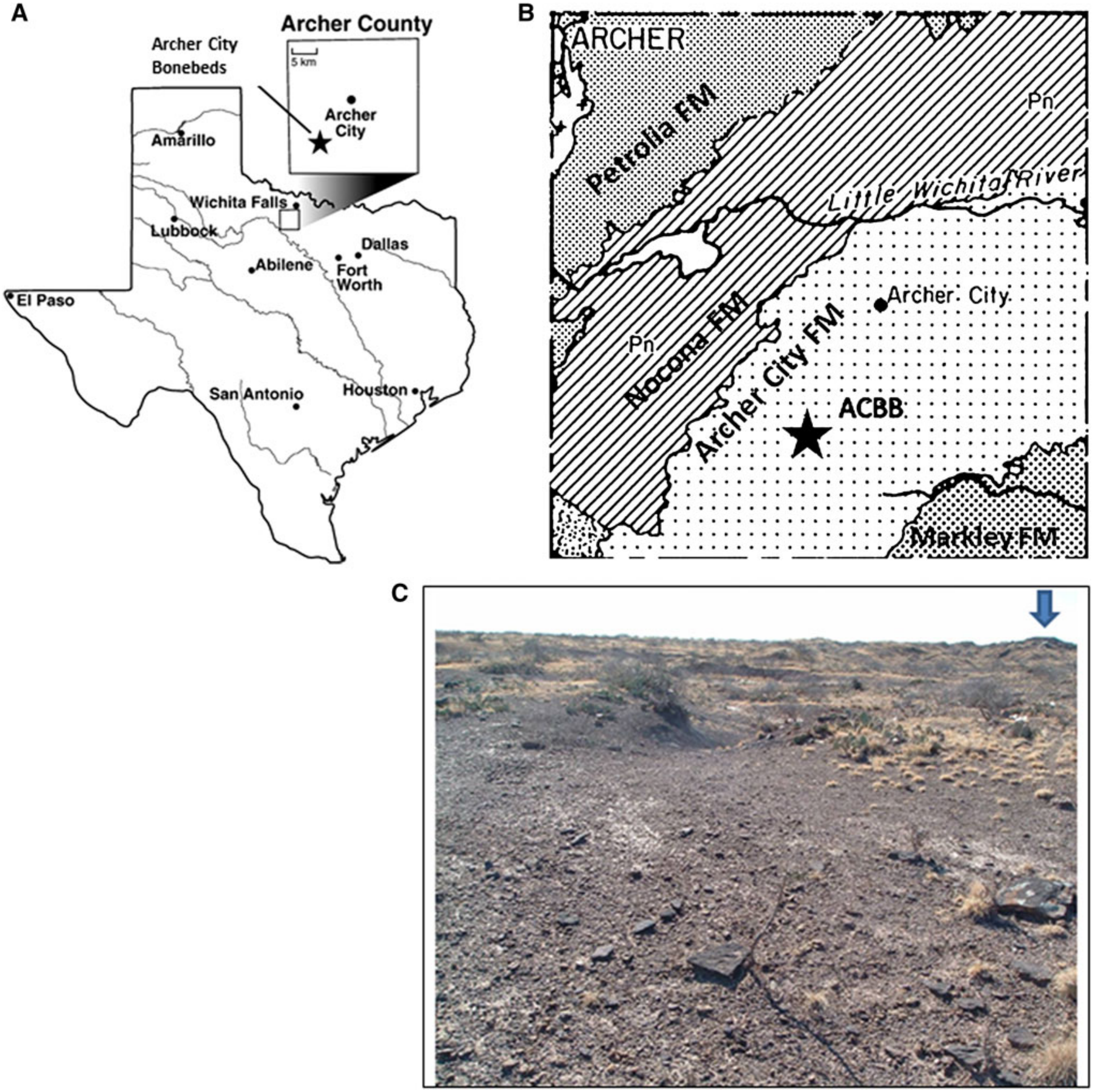


Fig. 3 **a** Map of Archer County, Texas, USA, showing the location of the Archer City Bone Beds (ACBB). **b** Geologic map showing the ACBBs set in the Lower Permian Archer City Formation (modified from Hentz 1988; Labandeira and Allen 2007). **c** Photograph of ACBB V in the foreground facing southwest (*arrow* indicates southwestern boundary of ACBB III)

in Baylor Co., Texas, USA, is based on external morphology and remains the standard for describing spiral bromalites. Heteropolar bromalites are those with relatively closely spaced turns concentrated towards one end (Fig. 2a). Amphipolar bromalites have blunt ends with wider and regularly spaced turns running along the entire length (Fig. 2b). Some experts have stated that these morphologies may ultimately provide little taxonomic information (Zidek 1980; McAllister 1985; Chin 1996), but this is not their only significance.

Geological setting

One of the localities which yielded the study material has not yet been described in the literature and is here named "Archer City Bonebed (ACBB) V" (TMM-45923, coordinates on file at the J.J. Pickle Lab Vertebrate Paleontology Department of the Univesity of Texas in Austin, Texas). The second locality is known as ACBB III (Sander 1989), and a general description is on file at the Texas Memorial Museum

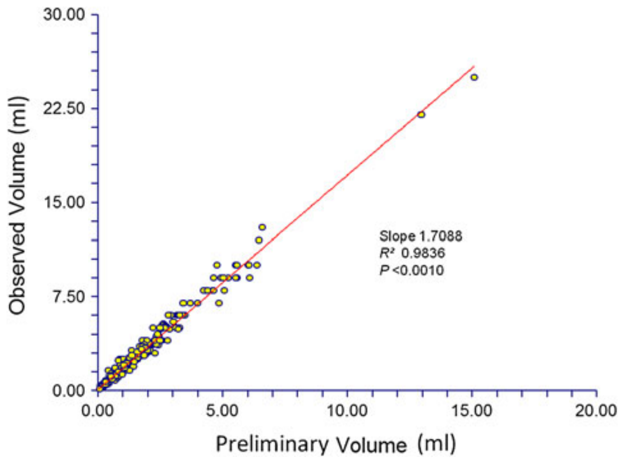


Fig. 4 Linear relationship between the calculated preliminary volumes and observed volumes. The calculations were done with the proposed volume formula. Observed volumes were obtained by recording water displacement using a graduated cylinder. The slope of the regression line (1.7088) is used as a constant in the proposed volume formula

at UT Austin (Fig. 3). ACBB V is very similar to ACBB III as described by Sander (1989). Both localities are located on the property of the Circle A Ranch within a few hundred meters of each other. The site is in Archer County approximately 4 km southwest of Archer City, Texas, USA (Fig. 3). The bonebed is situated in the Archer City Formation, the uppermost formation of the Bowie Group in the Texas Lower Permian (Hentz 1988; Wardlaw et al. 2004). This is one of many bonebeds that occur locally (Romer and Price 1940; Sander 1987, 1989); the overall lithology, which is mostly gray mudstone, is again identical to that of ACBB III (Sander 1989). Stratigraphy follows that of Hentz (1988).

Evidence of Lower Permian vertebrates from both terrestrial and aquatic organisms have been collected from these and surrounding localities in Archer County, Texas, for over a century (Case 1915; Romer 1928; Cope 1878). Spiral bromalites are of the most distinctive fossilized remains found of vertebrates from the Lower Permian in this area (Amstutz 1958; Olson 1966; Häntzschel et al. 1968; Sander 1989). Presently, spiral bromalites are attributed to marine and freshwater fish that retained the spiral intestinal valve (Parker 1885; Bertin 1958; McAllister 1987; Holmgren et al. 1999). It is a pliesiomorphic condition of present day sharks. However, agnathans, lungfish, gars, and bowfins possess it as well (Gilmore 1992). Spiral intestinal valves may have been secondarily lost during the evolution of tetrapods, if they ever possessed them at all (Romer and Parsons 1986).

In addition to the spiral bromalites found at the ACBBs, other remains found in abundance at these sites presumed to be from the extinct freshwater xenacanth shark *Orthacanthus,* included vertebrae, fossilized cartilage, scales, and teeth (Schneider 1996). Not only are *O. texensis* teeth

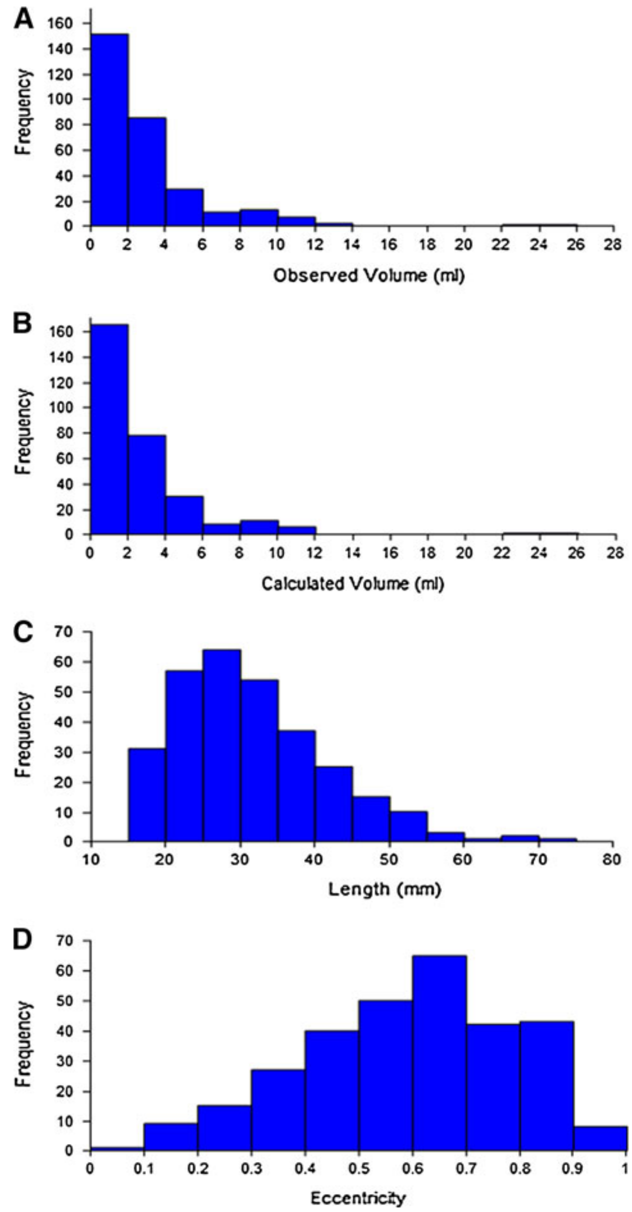


Fig. 5 Sample distribution of the spiral heteropolar bromalites from Archer City Bonebed III and V, $n = 300$. The **a** observed volume and the **b** calculated volume show a similar distribution pattern both indicating a decrease in specimens with large volumes. **c** Length shows a bell curve distribution giving to the possibility that a single species is present in the sample set. **d** Eccentricity, there is a bell cure distribution on the degree of flatness preserved in these specimens. There is a trend towards the more crushed state

found at the ACBBs but also the teeth of *O. compresus*, which are both very similar in appearance (Gary Johnson, personal communication 2005).

ACBB V yielded additional vertebrate material from reptiles and amphibians including pelycosaur neural spines, *Archeria* vertebrae, and fragmented dermal skull bones of *Eryops.* Fossil flora observed at the site consisted of *Walchia* impressions preserved in hematitic nodules, a plant indicative

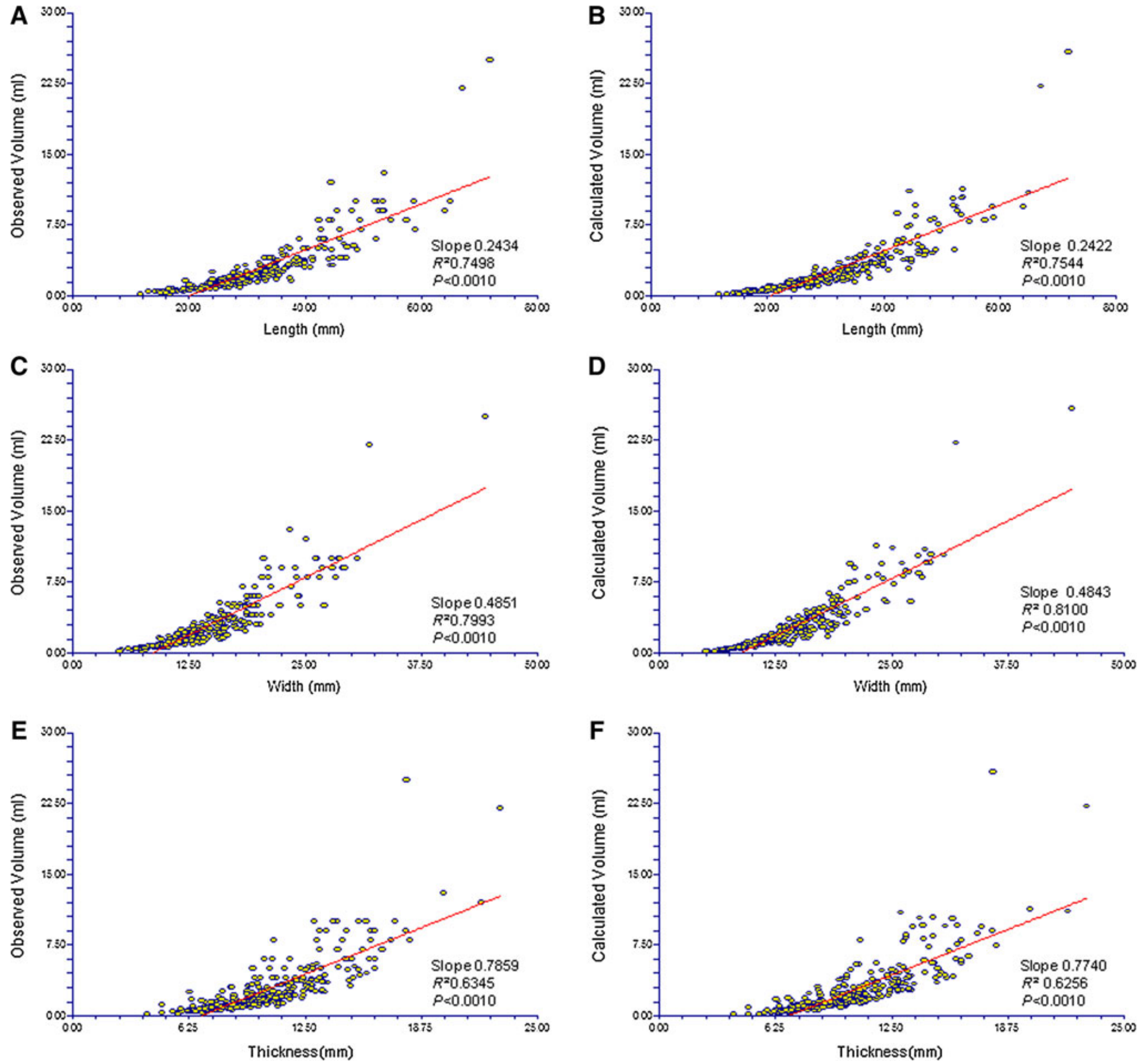


Fig. 6 Linear relationship between the three physical measurements of each of the spiral heteropolar bromalites with respect to the observed water displacement and calculated volumes, $n = 300$. Comparison of the two regressions shows similar results between the respected volumes. **a** Linear relationship between the lengths and the observed water displacement volumes ($R^2 = 0.75$). **b** Linear relationship between the lengths and the calculated volumes ($R^2 = 0.75$). **c** Linear relationship between the widths and the observed water displacement volumes ($R^2 = 0.8$). **d** Linear relationship between the widths and the calculated volumes. ($R^2 = 0.8$) **e** Linear relationship between the thickness and the observed water displacement volumes ($R^2 = 0.63$). **f** Linear relationship between the thickness and the calculated volumes ($R^2 = 0.63$)

of Permian delta margins (Read and Mamay 1964; DiMichele et al. 2001). Invertebrate fossils were not found.

Materials and methods

In the North Texas Lower Permian, spiral bromalites most often erode out of their encasing sediments and are collected as float. However, the informative value of bromalites is greatly enhanced when they are collected in situ and can be correctly placed within a detailed stratigraphic column (Chin 2002). All 1,070 spiral bromalites found during this study were surface collected between 2003 and 2006. Of these, 300 heteropolar specimens were used for statistical analysis. <20 amphipolar spiral bromalites were found, but they were not used because of their incompleteness. In the lab, all specimens were cleaned in a soap and water solution to remove excess dirt and allowed to dry for several hours at room temperature. Each spiral bromalite was numbered using a personal field catalog system (CDS-#) at the time of collection. All fossil material used for this study is housed in the vertebrate fossil collection of the J.J. Pickle Lab Vertebrate Paleontology Department of UT AUSTIN (TMM 45923-#) Austin, Texas, USA (see "Appendix").

Measurements

The study set of 300 near complete, heteropolar spiral bromalites was chosen at random for use as a representative sample of the specimens found at the bonebed. Each bromalite was weighed on a Mettler Toledo PB303-S digital weight scale to the nearest 0.001 g. Length, greatest width, and thickness (which was taken at 90° from the greatest width) (Fig. 1a) were measured with Mitutoyo Digimatic 500-133 CD-6"B calipers to the nearest 0.01 mm (see "Appendix"). The length is considered the longest linear measurement available. The width is recorded as the longest measurement perpendicular to length. Last, thickness was taken at 90° from where the width is recorded, which is essentially the shortest measurement. The degree of flatness was calculated for each spiral bromalite using the Euclidean geometric formula for finding the eccentricity of an ellipse. Eccentricity (e) is mathematically defined as the deviation of an ellipse from the true circular form, determined by utilizing the ratio of the major and minor diameter, which is the width (w) and thickness (t), respectively (Fig. 1b).

$$e = \sqrt{1 - \left(\frac{t^2}{w^2}\right)}$$

The closer the eccentricity value is to zero the more round the ellipse is, and the closer it is to a perfect circle. When the value is closer to one, the specimen is flatter or more "crushed".

Volume was first determined by placing each spiral bromalite in a water-filled graduated cylinder to measure displacement. A variety of graduated cylinders (10, 100, and 200 ml) were needed to accommodate the varying sizes of the bromalites. These measurements are referred to as the "observed" volume (see "Appendix"). Density was also calculated for each spiral bromalite utilizing each specimen's calculated and observed volume measurements (see "Appendix").

New volume formula

Using the three linear measurements, volume (V) was also calculated using the new formula (Fig. 1a). Length (l), width (w), and thickness (t) are multiplied together. The resulting product is then multiplied by Pi (π) and divided by 12,000 to convert the measured units.

$$V = \int_0^l \pi\left(\frac{w}{2l}\right)x\left(\frac{t}{2l}\right)xdx = \left(\frac{\pi lwt}{12}\right)\left(\frac{1}{1{,}000}\right) = \frac{\pi(lwt)}{12{,}000}(1.7088)$$

The "preliminary" volumes were compared with the observed volumes by linear regression. These data were analyzed with the Number Cruncher Statistical Systems (NCSS) 2001 software. A slope of 1.7088 and an R^2 value of 0.9836 were found (Fig. 4). The slope (1.7088) was used as a constant (Fig. 5) and every "preliminary" volume was multiplied by this number. These results are referred to as the "calculated" volumes (see "Appendix").

Histograms and linear regressions

Histograms were produced using Microsoft Excel 2010 to show the grouping and distribution of values for the observed and calculated volumes, length, and eccentricity of the 300 spiral bromalites (Fig. 5). The three linear measurements were each regressed against both the observed and calculated volumes (Fig. 6).

Results

Linear dimensions and volumes

Overall length of the 300 spiral bromalites ranged from 11.77 to 71.98 mm with a mean of 31.74 mm, and greatest width was between 5.07 and 44.52 mm with a mean of 14.43 mm. Height ranged from 4.00 to 23.04 mm with a mean of 10.51 mm, and eccentricity was found to be between 0.06 and 0.9 with a mean of 0.6. Mass was between 0.277 and 68.861 g with a mean of 7.971 g (see "Appendix" for complete dataset).

The spiral bromalites had a mean observed volume of 2.8 ml $\pm$ 3.0, and a mean calculated volume of 2.8 ml $\pm$ 2.9. Observed volume was in the range of 0.1–25 ml, and the calculated volume had a range of 0.11 to 25.8 ml. Absolute differences between the observed and calculated volumes ranged between 0.001063 and 1.824556 ml. The absolute difference in the densities ranged between 0.000879 and 1.811996 g/ml (see "Appendix"). The percentage differences between the observed and calculated volumes and their respective densities ranged from 0.04 to 56 %. 95 % of the statistical sample had a percent difference of <30.

Linear regressions between the volumes and physical characteristics have R^2 values and slopes that are very similar when compared with the observed and calculated volumes (Fig. 6). For example, Fig. 6a and b show the regressions for length, R^2 values 0.7498 and 0.7544, slopes of 0.2434 and 0.2422.

When comparing the two volume histograms, they show an almost identical result (Fig. 5a, b). 40 % of all bromalites (120) occur between zero and 1.5 ml (see "Appendix"). Length shows a bell curve with the greatest concentration between 20 and 35 mm (Fig. 5c). This suggests that only one species of fish produced the spiral bromalites studied.

Eccentricity and testing William's prediction

Like the length histogram, the eccentricity histogram also shows a bell curve with 50 % between 0.6 and 0.9 (Fig. 5d). 2.7 % fall between 0.9 and 1.0, which is approaching extreme flatness. Only 0.3 % of the bromolites fall between 0 and 0.1, the most unaltered end of the scale.

The 300 specimen used in the statistical analysis showed an average length to width ratio of 2.2:1. Williams (1972) predicted that a comparison with uncrushed spiral bromalites from Texas could reveal the length to width ratio is closer to 2.5:1. It is interesting to note that if only the spiral bromalites with eccentricity values from 0 to 0.3 are used, we find 24 out of 300 (8 %) in the statistical collection meet this criterion (see "Appendix"). The resulting length to width ratio of these 24 specimens is 2.5:1. In these cases William's prediction was correct. In contrast, 50 out of 300 (17 %) have an eccentricity ranging from 0.8 to 1.0, with a length to width ratio of 1.94:1, these of course being the most crushed (see "Appendix").

Discussion and conclusions

Published data sets (linear measurements with accompanying volume) from other spiral bromalites could not be found for comparison in the literature. However, Chin et al. (1998) reported the length (44 cm), width (16 cm), and thickness (13 cm) of a probable *Tyrannosaurus rex* coprolite with an accompanying volume of 2.4 L. This volume was obtained by first determining the density of a representative piece of the coprolite using water displacement and then extrapolating the volume of the entire mass by correlating the density with the total weight of the specimen (Karen Chin: personal communication 2005). The volume of the probable *T. rex* coprolite was calculated using the new volume formula (Fig. 1) given the three dimensions reported by Chin et al. (1998). The resulting calculated volume was 2.39 L, without multiplying by the constant (1.7088). Another example involves a similar supposed *T. rex* coprolite published by Chin et al. (2003). They reported the dimensions of length (64 cm), width (17 cm), and thickness (8 to 16 cm), with a conservative estimated volume to be 6 L. With the variation in thickness an estimated volume of 3.89 to 7.78 L is found using the new formula, this time the constant (1.7088) was used. The *T. rex* comparison is an interesting coincidence as this formula was developed with the use of presumed freshwater shark bromalites.

The bromalite volume formula needs to be further tested on other spiral bromalite collections not only from the Lower Permian but also from other geologic ages in general to compare the values and to check accuracy and consistency of the calculations and the constant. A comparison of morphometric data from spiral amphipolar bromalites (Fig. 2b) needs to be done as well . From the data we can only interpret a single species produced the heteropolar bromalites indicated by the bell curve in the length histogram (Fig. 5c). It is obvious by the presence of the amphipolar bromalites, however, that at least a second species coexisted here with the species producing the spiral heteropolar bromalites. This warrants a closer look at the microvertebrate fauna and differences in morphology of the shark teeth from the site Johnson (1992, 1996, 1999).

Problems with this formula include accuracy of the physical measurements, which would be skewed due to any extra matrix adhered on the specimen. Also, the formula assumes that all specimens terminate in a point, but many bromalites are incomplete or have blunt tips, due to damage, erosion, or lack of preservation. This would allow some room for error and perhaps explain the high percent difference in some specimens (see "Appendix").

Data from this study and the formula developed here will help to understand not only the spiral bromalites from ACBB III and V, but also bromalites from different localities, geological ages, and different origins. A standard precedent for classifying these fossils based on external as well as internal morphometric data is crucial to understanding their origin and producers.

Acknowledgments I would like to thank the owner of the Circle A Ranch, George Allan, for giving me access to his land and permission to collect, and also, Shane Bagley and Dave Wallace for their help in locating the bonebed. Steven Tudor, Mike Pettibon, Pam Buzas-Stephens, and "Geo" Jack Kelley are thanked for helping with collecting specimens. Thanks goes to Jack Loftin of Archer County Texas for his assistant, lending specimens, and providing background on the area. I want to thank Pat Mitchell (Midwestern State University) for help deriving the new volume formula, and Joel Schmitter (Midwestern State University) for lending his expertise in statistics. I also would like to thank Karen Chin of the University of Colorado Boulder for her expertise in coprolites, for sending article reprints, and her willingness to communicate with me. I would also like to thank Gary Johnson of the Southern Methodist University for his expertise in Paleozoic sharks, willingness to share specimens, and for sending reprints of his articles. I thank Fred Stangl (Midwestern State University) for allowing me to use his lab and equipment, help with the NCSS program, and for his editorial critiques. I want to recognize and thank Michael Shipley (Midwestern State University) for the use of his lab and supplies and for his guidance. I would also like to acknowledge and thank Adrian Hunt (New Mexico Museum of Natural History), Conrad Labandeira (Smithsonian Institute) and Tucker Hentz (Bureau of Economic Geology of Texas) for allowing the reproduction and use of their figures, modified for this study. Finally I would like to thank Martin Sander, from the University of Bonn, for his advice, editing and for picking up where others have left off.

Appendix

See Table 1.

Table 1 Physical characteristics of 300 spiral heteropolar bromalites from Archer City Bonebeds III and V

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-1	CDS-1	52.77	21.11	17.96	26.36	0.53	9	2.93	8.95	2.95	0.05	0.02	0.55
TMM 45923-2	CDS-2	53.64	23.45	19.99	36.15	0.52	13	2.78	11.25	3.21	1.75	0.43	13.47
TMM 45923-3	CDS-3	59.08	23.6	13.32	21.29	0.83	7	3.04	8.31	2.56	1.31	0.48	15.75
TMM 45923-4	CDS-6	45.58	27.99	14.76	24.65	0.85	9	2.74	8.42	2.93	0.58	0.19	6.40
TMM 45923-5	CDS-8	46.03	24.46	10.77	16.54	0.90	6	2.76	5.42	3.05	0.58	0.29	9.59
TMM 45923-6	CDS-9	34.42	18.77	10.96	8.97	0.81	4	2.24	3.17	2.83	0.83	0.59	20.80
TMM 45923-7	CDS-10	34.28	15.57	9.67	6.31	0.78	2.2	2.87	2.31	2.73	0.11	0.14	4.72
TMM 45923-8	CDS-11	42.48	26.59	17.14	23.84	0.76	8	2.98	8.66	2.75	0.66	0.23	7.64
TMM 45923-9	CDS-15	25.5	12.38	10.95	4.53	0.47	1.8	2.51	1.55	2.93	0.25	0.41	14.08
TMM 45923-10	CDS-17	44.5	13.17	11.08	9.43	0.54	3.2	2.95	2.91	3.25	0.29	0.30	9.22
TMM 45923-11	CDS-19	48.76	26.3	14.25	24.56	0.84	10	2.46	8.18	3.00	1.82	0.55	18.25
TMM 45923-12	CDS-21	38.44	16.93	11.67	10.21	0.72	3.4	3.00	3.40	3.00	0.00	0.00	0.07
TMM 45923-13	CDS-22	26.38	11.05	10.62	4.38	0.28	1.4	3.13	1.38	3.16	0.02	0.03	1.07
TMM 45923-14	CDS-23	47.34	17.4	12.73	14.39	0.68	5.1	2.82	4.69	3.07	0.41	0.25	8.02
TMM 45923-15	CDS-26	41.31	21.4	10.09	9.93	0.88	4	2.48	3.99	2.49	0.01	0.01	0.24
TMM 45923-16	CDS-27	22.74	8.93	8.6	2.08	0.27	0.7	2.97	0.78	2.66	0.08	0.31	10.41
TMM 45923-17	CDS-33	34.49	14.75	10.15	6.59	0.73	2.3	2.87	2.31	2.85	0.01	0.01	0.44
TMM 45923-18	CDS-34	28.47	12.04	7.41	2.92	0.79	1	2.92	1.14	2.57	0.14	0.35	12.00
TMM 45923-19	CDS-35	38	17.64	11.79	9.67	0.74	3.4	2.84	3.54	2.73	0.14	0.11	3.84
TMM 45923-20	CDS-36	31.85	15.95	7.15	4.11	0.89	1.4	2.94	1.62	2.53	0.22	0.41	13.85
TMM 45923-21	CDS-37	33.79	18.67	10.46	9.57	0.83	3	3.19	2.95	3.24	0.05	0.05	1.59
TMM 45923-22	CDS-43	33.9	15.81	9.68	6.56	0.79	2.4	2.73	2.32	2.83	0.08	0.09	3.29
TMM 45923-23	CDS-44	32.52	16.35	10.2	7.79	0.78	2.6	3.00	2.43	3.21	0.17	0.21	6.68
TMM 45923-24	CDS-47	28.58	12.61	9.76	5.33	0.63	1.9	2.80	1.57	3.38	0.33	0.58	17.18
TMM 45923-25	CDS-48	28.16	15.62	13.49	7.67	0.50	2.5	3.07	2.65	2.89	0.15	0.18	5.82
TMM 45923-26	CDS-50	39.96	20.05	8.55	8.78	0.90	3	2.93	3.06	2.86	0.06	0.06	2.11
TMM 45923-27	CDS-53	42.35	18.59	13.35	15.47	0.70	5	3.09	4.70	3.29	0.30	0.20	5.96
TMM 45923-28	CDS-54	46.13	19.27	11.99	12.23	0.78	4	3.06	4.77	2.57	0.77	0.49	16.11
TMM 45923-29	CDS-56	29.76	13.18	8.67	4.09	0.75	1.3	3.14	1.52	2.69	0.22	0.46	14.55
TMM 45923-30	CDS-57	36.6	15.65	12.68	8.31	0.59	2.9	2.87	3.25	2.56	0.35	0.31	10.75
TMM 45923-31	CDS-59	21.29	8.64	8.45	2.29	0.21	0.8	2.86	0.70	3.29	0.10	0.43	13.08
TMM 45923-32	CDS-60	33.82	12.28	11.13	6.65	0.42	2.2	3.02	2.07	3.22	0.13	0.19	6.00
TMM 45923-33	CDS-64	40.12	19.15	16.3	14.93	0.52	5	2.99	5.60	2.66	0.60	0.32	10.76
TMM 45923-34	CDS-65	28.34	12.76	11.81	5.29	0.38	2	2.65	1.91	2.77	0.09	0.12	4.47

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-35	CDS-67	47.11	20.36	10.09	12.65	0.87	4	3.16	4.33	2.92	0.33	0.24	7.62
TMM 45923-36	CDS-70	37.61	15.9	12.96	8.40	0.58	3.2	2.63	3.47	2.42	0.27	0.20	7.71
TMM 45923-37	CDS-71	35.72	18.29	8.11	8.02	0.90	2.6	3.09	2.37	3.38	0.23	0.30	8.83
TMM 45923-38	CDS-73	29.42	15.41	9.44	4.88	0.79	2	2.44	1.91	2.55	0.09	0.11	4.27
TMM 45923-39	CDS-77	23.55	13.21	9.66	4.27	0.68	1.4	3.05	1.34	3.18	0.06	0.13	3.97
TMM 45923-40	CDS-78	28.75	13.57	12.36	5.45	0.41	1.9	2.87	2.16	2.52	0.26	0.34	11.93
TMM 45923-41	CDS-79	40.89	17.42	8.57	7.50	0.87	3	2.50	2.73	2.74	0.27	0.25	8.97
TMM 45923-42	CDS-80	32.08	11.3	10.35	5.30	0.40	2	2.65	1.68	3.16	0.32	0.51	16.07
TMM 45923-43	CDS-83	25.99	12.99	7.13	2.89	0.84	1	2.89	1.08	2.68	0.08	0.21	7.14
TMM 45923-44	CDS-84	25.83	10.86	10.19	4.50	0.35	1.6	2.81	1.28	3.51	0.32	0.71	20.07
TMM 45923-45	CDS-85	20.52	12.98	7.78	2.63	0.80	0.9	2.93	0.93	2.84	0.03	0.09	2.92
TMM 45923-46	CDS-86	22.49	10.15	8.99	2.91	0.46	0.9	3.24	0.92	3.17	0.02	0.06	1.97
TMM 45923-47	CDS-87	20.8	11.57	9.34	2.82	0.59	1	2.82	1.01	2.80	0.01	0.02	0.56
TMM 45923-48	CDS-91	39.51	15.81	12.52	10.78	0.61	3.6	3.00	3.50	3.08	0.10	0.09	2.81
TMM 45923-49	CDS-96	32.47	16.11	14.99	9.63	0.37	3.1	3.11	3.51	2.75	0.41	0.36	11.63
TMM 45923-50	CDS-98	26.15	10.77	9.05	3.30	0.54	1.1	3.00	1.14	2.89	0.04	0.11	3.53
TMM 45923-51	CDS-100	28.08	11.93	10.82	4.42	0.42	1.6	2.76	1.62	2.73	0.02	0.04	1.33
TMM 45923-52	CDS-108	33.17	15.63	6.42	4.84	0.91	1.7	2.85	1.49	3.25	0.21	0.40	12.41
TMM 45923-53	CDS-109	33.66	15.44	7.86	5.76	0.86	2	2.88	1.83	3.15	0.17	0.27	8.62
TMM 45923-54	CDS-114	26.42	10.34	9.62	3.78	0.37	0.8	4.72	1.18	3.21	0.38	1.51	31.96
TMM 45923-55	CDS-118	28.18	11.83	9.69	3.90	0.57	1.3	3.00	1.45	2.70	0.15	0.30	10.05
TMM 45923-56	CDS-123	24.37	12.48	9.16	3.74	0.68	1.3	2.88	1.25	3.00	0.05	0.12	4.13
TMM 45923-57	CDS-125	33.3	16.56	10.55	8.80	0.77	2.7	3.26	2.60	3.38	0.10	0.12	3.60
TMM 45923-58	CDS-128	41.39	17.49	12.33	10.35	0.71	3.7	2.80	3.99	2.59	0.29	0.21	7.34
TMM 45923-59	CDS-129	43.26	24.28	11.73	14.34	0.88	6	2.39	5.51	2.60	0.49	0.21	8.13
TMM 45923-60	CDS-130	34.97	14.23	10.75	7.93	0.66	2.4	3.30	2.39	3.31	0.01	0.01	0.28
TMM 45923-61	CDS-131	37.07	14.38	11.89	8.52	0.56	3	2.84	2.84	3.00	0.16	0.16	5.48
TMM 45923-62	CDS-132	22.32	9.84	7.86	2.24	0.60	0.6	3.74	0.77	2.91	0.17	0.83	22.31
TMM 45923-63	CDS-133	30.29	13.68	10	5.38	0.68	1.9	2.83	1.85	2.90	0.05	0.07	2.43
TMM 45923-64	CDS-140	17.26	9.37	7.31	2.28	0.63	0.8	2.85	0.53	4.31	0.27	1.46	33.89
TMM 45923-65	CDS-141	24.95	12.15	7.27	2.70	0.80	0.9	3.00	0.99	2.74	0.09	0.26	8.72
TMM 45923-66	CDS-143	23.51	11.56	11.06	4.71	0.29	1	4.71	1.34	3.50	0.34	1.21	25.64
TMM 45923-67	CDS-144	19.48	9.4	8.64	1.88	0.39	1.6	1.17	0.71	2.65	0.89	1.48	55.76
TMM 45923-68	CDS-145	23.81	9.25	8.75	2.33	0.32	0.9	2.59	0.86	2.70	0.04	0.11	4.20

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-69	CDS-146	23.67	12.53	11.11	3.77	0.46	1.4	2.69	1.47	2.56	0.07	0.14	5.03
TMM 45923-70	CDS-147	18.88	7.35	6.62	1.29	0.43	0.6	2.15	0.41	3.14	0.19	0.99	31.50
TMM 45923-71	CDS-149	20.38	11.22	10.05	3.19	0.44	1	3.19	1.03	3.10	0.03	0.09	2.73
TMM 45923-72	CDS-154	39.2	19.02	15.01	15.87	0.61	6	2.64	5.01	3.17	0.99	0.52	16.55
TMM 45923-73	CDS-155	44.7	20.45	18.2	18.60	0.46	8	2.32	7.44	2.50	0.56	0.17	6.96
TMM 45923-74	CDS-160	36.35	13.86	11.77	7.75	0.53	2.5	3.10	2.65	2.92	0.15	0.18	5.76
TMM 45923-75	CDS-161	24.11	12.6	11.14	4.58	0.47	2.5	1.83	1.51	3.03	0.99	1.19	39.44
TMM 45923-76	CDS-162	28.74	10.38	9.93	3.46	0.29	1.3	2.66	1.33	2.61	0.03	0.05	1.91
TMM 45923-77	CDS-163	37.64	16.23	6.96	4.87	0.90	1.6	3.04	1.90	2.56	0.30	0.48	15.89
TMM 45923-78	CDS-164	39.39	16.57	13.43	10.53	0.59	3.7	2.85	3.92	2.68	0.22	0.16	5.65
TMM 45923-79	CDS-165	23.6	11.68	10.88	4.32	0.36	1.5	2.88	1.34	3.22	0.16	0.34	10.55
TMM 45923-80	CDS-166	26.13	11.94	11.2	5.21	0.35	1.9	2.74	1.56	3.33	0.34	0.59	17.72
TMM 45923-81	CDS-167	20.49	9.63	8.06	2.08	0.55	0.8	2.60	0.71	2.92	0.09	0.32	11.06
TMM 45923-82	CDS-169	25.69	12.78	10.5	4.41	0.57	1.4	3.15	1.54	2.86	0.14	0.29	9.22
TMM 45923-83	CDS-170	29.53	13.04	11.09	5.32	0.53	1.8	2.96	1.91	2.79	0.11	0.17	5.78
TMM 45923-84	CDS-171	18.37	8.13	6.37	1.39	0.62	0.5	2.78	0.43	3.27	0.07	0.49	14.88
TMM 45923-85	CDS-175	25.09	13.69	6.5	3.02	0.88	1	3.02	1.00	3.03	0.00	0.00	0.12
TMM 45923-86	CDS-176	19.92	7.41	7.33	1.72	0.15	0.6	2.87	0.48	3.55	0.12	0.69	19.33
TMM 45923-87	CDS-182	25.06	11.01	10.99	3.95	0.06	1.3	3.04	1.36	2.91	0.06	0.13	4.17
TMM 45923-88	CDS-183	28.15	14.66	8.82	4.71	0.80	1.7	2.77	1.63	2.89	0.07	0.12	4.21
TMM 45923-89	CDS-185	26.67	14.44	7.7	3.77	0.85	1.4	2.69	1.33	2.84	0.07	0.15	5.24
TMM 45923-90	CDS-198	23.44	11.89	9.86	3.90	0.56	1.3	3.00	1.23	3.17	0.07	0.17	5.43
TMM 45923-91	CDS-199	24.99	13.42	8.22	3.35	0.79	1.1	3.04	1.23	2.71	0.13	0.33	10.81
TMM 45923-92	CDS-203	15.6	6.47	5.67	0.83	0.48	0.3	2.77	0.26	3.24	0.04	0.48	14.66
TMM 45923-93	CDS-204	19.39	9.26	7.32	1.84	0.61	0.6	3.06	0.59	3.13	0.01	0.06	2.00
TMM 45923-94	CDS-205	21.47	10.74	7.97	2.37	0.67	0.8	2.96	0.82	2.88	0.02	0.08	2.70
TMM 45923-95	CDS-207	14.3	6.78	6.37	0.87	0.34	0.4	2.16	0.28	3.13	0.12	0.97	30.92
TMM 45923-96	CDS-209	17.76	9.24	8.02	1.59	0.50	0.6	2.65	0.59	2.70	0.01	0.05	1.87
TMM 45923-97	CDS-210	14.95	7.31	6.99	0.96	0.29	0.4	2.39	0.34	2.80	0.06	0.41	14.56
TMM 45923-98	CDS-212	16.89	7.47	5.69	0.91	0.65	0.2	4.53	0.32	2.82	0.12	1.71	37.73
TMM 45923-99	CDS-215	13.15	5.98	5.38	0.65	0.44	0.4	1.63	0.19	3.44	0.21	1.81	52.68
TMM 45923-100	CDS-229	24.71	9.57	8.02	2.53	0.55	0.9	2.81	0.85	2.98	0.05	0.17	5.73
TMM 45923-101	CDS-230	25.86	13.69	11.01	4.30	0.59	1.7	2.53	1.74	2.46	0.04	0.06	2.51
TMM 45923-102	CDS-232	38.11	15.41	13.16	10.87	0.52	3.7	2.94	3.46	3.14	0.24	0.21	6.55

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-103	CDS-234	31.69	17.69	10.8	7.07	0.79	2.6	2.72	2.71	2.61	0.11	0.11	4.01
TMM 45923-104	CDS-237	26.24	13.71	10.33	5.81	0.66	1.9	3.06	1.66	3.49	0.24	0.44	12.50
TMM 45923-105	CDS-238	31.04	13.37	10.69	6.90	0.60	2.1	3.29	1.98	3.48	0.12	0.19	5.49
TMM 45923-106	CDS-242	36.85	18.74	13.6	12.18	0.69	4.3	2.83	4.20	2.90	0.10	0.07	2.29
TMM 45923-107	CDS-243	44.82	19.81	9.82	12.47	0.87	4	3.12	3.90	3.20	0.10	0.08	2.48
TMM 45923-108	CDS-246	35.09	20.28	10.01	9.36	0.87	3	3.12	3.19	2.94	0.19	0.18	5.86
TMM 45923-109	CDS-247	27.51	14.06	4.8	3.52	0.94	1.2	2.93	0.83	4.24	0.37	1.30	30.78
TMM 45923-110	CDS-249	30.45	12.58	9.37	4.40	0.67	1.6	2.75	1.61	2.74	0.01	0.01	0.36
TMM 45923-111	CDS-250	33.17	19.15	10.76	11.91	0.83	4	2.98	3.06	3.89	0.94	0.92	23.56
TMM 45923-112	CDS-252	44.23	15.04	12.85	11.90	0.52	3.9	3.05	3.82	3.11	0.08	0.06	1.94
TMM 45923-113	CDS-254	34.51	18.99	9.48	9.39	0.87	3.1	3.03	2.78	3.38	0.32	0.35	10.34
TMM 45923-114	CDS-256	24.88	9.12	8.02	2.08	0.48	0.8	2.61	0.81	2.56	0.01	0.05	1.74
TMM 45923-115	CDS-258	27.75	13.44	8.62	3.70	0.77	1.2	3.08	1.44	2.57	0.24	0.51	16.57
TMM 45923-116	CDS-259	33.98	18.2	6.3	7.29	0.94	2.5	2.92	1.74	4.18	0.76	1.27	30.28
TMM 45923-117	CDS-263	48.51	15.93	12.96	15.27	0.58	5.3	2.88	4.48	3.41	0.82	0.53	15.46
TMM 45923-118	CDS-265	36.91	18.02	15.18	14.63	0.54	5.2	2.81	4.52	3.24	0.68	0.43	13.14
TMM 45923-119	CDS-266	29.59	11.57	10.98	5.26	0.32	2	2.63	1.68	3.13	0.32	0.50	15.91
TMM 45923-120	CDS-269	43.42	19.22	15.97	16.20	0.56	6	2.70	5.96	2.72	0.04	0.02	0.63
TMM 45923-121	CDS-271	45.61	29.15	16.05	22.83	0.83	9	2.54	9.55	2.39	0.55	0.15	5.73
TMM 45923-122	CDS-277	35.03	15.58	13.77	9.91	0.47	3.5	2.83	3.36	2.95	0.14	0.12	3.94
TMM 45923-123	CDS-278	32.35	15.59	12.86	8.80	0.57	3.3	2.67	2.90	3.03	0.40	0.37	12.07
TMM 45923-124	CDS-280	42.87	21.36	14.29	19.60	0.74	7	2.80	5.85	3.35	1.15	0.55	16.37
TMM 45923-125	CDS-281	43.01	16.72	14.32	14.66	0.52	5.1	2.87	4.61	3.18	0.49	0.31	9.67
TMM 45923-126	CDS-284	25.52	11.02	7.47	3.43	0.74	1.4	2.45	0.94	3.65	0.46	1.20	32.87
TMM 45923-127	CDS-285	36.33	16	15.48	11.86	0.25	4.3	2.76	4.03	2.95	0.27	0.19	6.38
TMM 45923-128	CDS-287	31.43	16.26	11.52	6.78	0.71	2.5	2.71	2.63	2.57	0.13	0.14	5.08
TMM 45923-129	CDS-288	49.12	17.8	12.54	14.95	0.71	4.9	3.05	4.91	3.05	0.01	0.00	0.11
TMM 45923-130	CDS-290	32.7	13.67	13.56	7.12	0.13	2.5	2.85	2.71	2.62	0.21	0.22	7.81
TMM 45923-131	CDS-291	46.17	16.93	12.45	12.23	0.68	4	3.06	4.35	2.81	0.35	0.25	8.13
TMM 45923-132	CDS-293	42.33	27.13	10.65	14.35	0.92	5	2.87	5.47	2.62	0.47	0.25	8.62
TMM 45923-133	CDS-297	32.55	13.44	12.88	7.44	0.29	2.7	2.75	2.52	2.95	0.18	0.20	6.64
TMM 45923-134	CDS-299	40.11	15.4	12.89	10.82	0.55	3.8	2.85	3.56	3.04	0.24	0.19	6.26
TMM 45923-135	CDS-300	48.2	22.6	16.29	24.63	0.69	9	2.74	7.94	3.10	1.06	0.37	11.79
TMM 45923-136	CDS-301	32.64	13.23	9.73	4.81	0.68	1.8	2.67	1.88	2.56	0.08	0.11	4.24

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-137	CDS-303	26.11	12.34	10.2	4.69	0.56	1.6	2.93	1.47	3.19	0.13	0.26	8.11
TMM 45923-138	CDS-304	34.52	13.78	11.69	6.58	0.53	2.5	2.63	2.49	2.64	0.01	0.01	0.49
TMM 45923-139	CDS-305	29.73	11.79	11.32	5.60	0.28	2.1	2.67	1.78	3.15	0.32	0.49	15.47
TMM 45923-140	CDS-306	44.94	14.01	12.68	9.08	0.43	3.2	2.84	3.57	2.54	0.37	0.30	10.41
TMM 45923-141	CDS-307	32.13	14.74	13.52	10.27	0.40	3.5	2.93	2.86	3.58	0.64	0.65	18.15
TMM 45923-142	CDS-309	33.75	14.88	9.42	7.26	0.77	2.6	2.79	2.12	3.43	0.48	0.64	18.60
TMM 45923-143	CDS-311	35.53	15.79	8.7	6.40	0.83	2.1	3.05	2.18	2.93	0.08	0.12	3.83
TMM 45923-144	CDS-312	37.02	15.85	12.55	9.66	0.61	3.1	3.12	3.29	2.93	0.19	0.18	5.90
TMM 45923-145	CDS-314	29.65	12.31	10.96	4.74	0.46	1.7	2.79	1.79	2.65	0.09	0.14	5.01
TMM 45923-146	CDS-316	31.78	13.43	12.46	6.40	0.37	2.1	3.05	2.38	2.69	0.28	0.36	11.73
TMM 45923-147	CDS-318	24.62	11.96	9.95	4.11	0.55	1.5	2.74	1.31	3.13	0.19	0.40	12.62
TMM 45923-148	CDS-320	26.44	13.6	9.78	4.53	0.69	1.6	2.83	1.57	2.88	0.03	0.05	1.67
TMM 45923-149	CDS-322	27.43	13.83	10.88	5.82	0.62	1.9	3.06	1.85	3.15	0.05	0.09	2.81
TMM 45923-150	CDS-328	24.22	9.55	7.92	2.14	0.56	0.9	2.38	0.82	2.61	0.08	0.23	8.94
TMM 45923-151	CDS-330	24.02	11.02	8.24	2.66	0.66	1	2.66	0.98	2.72	0.02	0.07	2.42
TMM 45923-152	CDS-331	28.91	13.53	11.3	6.37	0.55	2.3	2.77	1.98	3.22	0.32	0.45	14.02
TMM 45923-153	CDS-336	17.75	7.61	6.18	1.02	0.58	0.4	2.55	0.37	2.73	0.03	0.18	6.63
TMM 45923-154	CDS-338	29.29	13.84	9.91	5.19	0.70	1.9	2.73	1.80	2.88	0.10	0.16	5.41
TMM 45923-155	CDS-341	28.36	18.61	12.71	7.44	0.73	3	2.48	3.00	2.48	0.00	0.00	0.04
TMM 45923-156	CDS-345	71.98	44.52	17.99	68.86	0.91	25	2.75	25.79	2.67	0.79	0.08	3.07
TMM 45923-157	CDS-350	34.4	13.67	13.48	6.97	0.17	2.7	2.58	2.84	2.46	0.14	0.12	4.79
TMM 45923-158	CDS-351	46.08	18.37	16.68	17.09	0.42	7	2.44	6.32	2.71	0.68	0.26	9.76
TMM 45923-159	CDS-352	39.99	17.26	13.44	9.69	0.63	3.6	2.69	4.15	2.33	0.55	0.36	13.26
TMM 45923-160	CDS-354	33.72	15.95	9.86	6.09	0.79	2.1	2.90	2.37	2.57	0.27	0.33	11.48
TMM 45923-161	CDS-357	28.19	16.28	11.05	6.73	0.73	2.2	3.06	2.27	2.97	0.07	0.09	3.03
TMM 45923-162	CDS-362	24.13	13.09	11.72	5.06	0.45	1.7	2.98	1.66	3.06	0.04	0.08	2.58
TMM 45923-163	CDS-366	52.1	27.93	15.81	29.97	0.82	10	3.00	10.29	2.91	0.29	0.09	2.84
TMM 45923-164	CDS-372	34.36	12.84	9.45	5.30	0.68	2.1	2.52	1.87	2.84	0.23	0.32	11.18
TMM 45923-165	CDS-378	44.55	25.21	22	35.95	0.49	12	3.00	11.05	3.25	0.95	0.26	7.88
TMM 45923-166	CDS-382	52.57	26.21	15.4	29.64	0.81	10	2.96	9.49	3.12	0.51	0.16	5.07
TMM 45923-167	CDS-386	42.66	18.75	16.26	17.98	0.50	6	3.00	5.82	3.09	0.18	0.09	3.02
TMM 45923-168	CDS-393	44.19	25.25	14.56	22.04	0.82	8	2.75	7.27	3.03	0.73	0.28	9.15
TMM 45923-169	CDS-400	58.93	20.59	17.4	27.71	0.53	10	2.77	9.45	2.93	0.55	0.16	5.55
TMM 45923-170	CDS-401	37.55	24.55	12.97	16.27	0.85	5	3.25	5.35	3.04	0.35	0.21	6.53

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-171	CDS-402	40.47	22.34	11.39	13.19	0.86	5	2.64	4.61	2.86	0.39	0.23	7.86
TMM 45923-172	CDS-407	15.58	6.75	6.52	0.87	0.26	0.4	2.18	0.31	2.84	0.09	0.66	23.31
TMM 45923-173	CDS-410	33.83	13.46	13.1	7.59	0.23	2.6	2.92	2.67	2.84	0.07	0.08	2.57
TMM 45923-174	CDS-413	29.83	12.26	10.95	5.13	0.45	1.9	2.70	1.79	2.87	0.11	0.16	5.71
TMM 45923-175	CDS-425	24.19	10.16	7.93	2.58	0.63	1	2.58	0.87	2.96	0.13	0.38	12.81
TMM 45923-176	CDS-428	22.4	11.33	8.99	3.05	0.61	1	3.05	1.02	2.99	0.02	0.06	2.03
TMM 45923-177	CDS-431	34.88	19.75	12.75	9.39	0.76	3	3.13	3.93	2.39	0.93	0.74	23.65
TMM 45923-178	CDS-437	35.3	17.3	11.62	9.07	0.74	2.8	3.24	3.17	2.86	0.37	0.38	11.80
TMM 45923-179	CDS-444	38.74	14.6	13.32	10.75	0.41	4	2.69	3.37	3.19	0.63	0.50	15.74
TMM 45923-180	CDS-453	20.06	10.63	8.84	2.29	0.56	0.9	2.55	0.84	2.72	0.06	0.17	6.30
TMM 45923-181	CDS-457	33.82	13.87	10.21	5.53	0.68	2	2.76	2.14	2.58	0.14	0.18	6.66
TMM 45923-182	CDS-458	30.62	12.99	11.92	5.85	0.40	2.1	2.79	2.12	2.76	0.02	0.03	1.00
TMM 45923-183	CDS-461	30.73	10.84	8.97	4.12	0.56	1.5	2.74	1.34	3.08	0.16	0.33	10.88
TMM 45923-184	CDS-462	30.07	16.38	12.44	6.88	0.65	2.6	2.65	2.74	2.51	0.14	0.14	5.15
TMM 45923-185	CDS-466	30.42	9.55	9.28	3.78	0.24	1.4	2.70	1.21	3.13	0.19	0.43	13.85
TMM 45923-186	CDS-472	18.03	7.7	7.13	1.24	0.38	0.4	3.10	0.44	2.80	0.04	0.30	9.68
TMM 45923-187	CDS-474	20.02	9.19	6.25	1.41	0.73	0.5	2.81	0.51	2.74	0.01	0.08	2.81
TMM 45923-188	CDS-475	21.85	8.81	7.67	1.55	0.49	0.5	3.09	0.66	2.34	0.16	0.75	24.30
TMM 45923-189	CDS-479	16.8	7.27	7.22	1.30	0.12	0.4	3.24	0.39	3.29	0.01	0.05	1.37
TMM 45923-190	CDS-481	26.35	12.08	11.13	3.99	0.39	1.3	3.07	1.58	2.51	0.28	0.55	17.98
TMM 45923-191	CDS-482	23.23	11.47	10	2.96	0.49	1	2.96	1.19	2.48	0.19	0.48	16.11
TMM 45923-192	CDS-483	26.55	11.61	9.55	3.90	0.57	1.2	3.25	1.32	2.96	0.12	0.29	8.88
TMM 45923-193	CDS-485	21.32	9.95	7.43	2.35	0.67	0.8	2.94	0.71	3.33	0.09	0.40	11.86
TMM 45923-194	CDS-486	20.95	10.29	6.99	2.03	0.73	0.8	2.54	0.67	3.01	0.13	0.47	15.73
TMM 45923-195	CDS-498	22.29	9.09	7.26	2.19	0.60	0.7	3.12	0.66	3.32	0.04	0.20	5.99
TMM 45923-196	CDS-499	23.49	11.88	9.47	3.40	0.60	1.2	2.83	1.18	2.88	0.02	0.04	1.48
TMM 45923-197	CDS-500	20.8	8.31	7.59	1.89	0.41	0.7	2.70	0.59	3.22	0.11	0.52	16.15
TMM 45923-198	CDS-501	54.93	24.2	13.17	22.89	0.84	8	2.86	7.83	2.92	0.17	0.06	2.10
TMM 45923-199	CDS-512	27.03	12.21	10.1	4.57	0.56	1.3	3.52	1.49	3.07	0.19	0.45	12.83
TMM 45923-200	CDS-516	35.32	16.92	14.92	10.65	0.47	3.7	2.88	3.99	2.67	0.29	0.21	7.25
TMM 45923-201	CDS-520	34.54	13.17	11.12	6.74	0.54	2.4	2.81	2.26	2.98	0.14	0.17	5.71
TMM 45923-202	CDS-524	30.12	12.05	8.28	4.08	0.73	1.5	2.72	1.34	3.03	0.16	0.31	10.37
TMM 45923-203	CDS-525	21.82	7.11	6.77	1.54	0.31	0.5	3.08	0.47	3.27	0.03	0.20	6.02
TMM 45923-204	CDS-529	26.98	12.09	10.65	5.66	0.47	2	2.83	1.55	3.64	0.45	0.81	22.29

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-205	CDS-531	26.95	9.23	8.19	2.71	0.46	0.9	3.01	0.91	2.97	0.01	0.04	1.25
TMM 45923-206	CDS-533	24.77	11.98	10.01	4.13	0.55	1.3	3.17	1.33	3.11	0.03	0.07	2.18
TMM 45923-207	CDS-537	23.42	10.96	7.95	2.88	0.69	1	2.88	0.91	3.15	0.09	0.27	8.71
TMM 45923-208	CDS-541	24.65	11.38	7.78	3.25	0.73	1.2	2.71	0.98	3.33	0.22	0.62	18.64
TMM 45923-209	CDS-543	27.89	10.44	9.82	3.62	0.34	1.4	2.58	1.28	2.83	0.12	0.24	8.63
TMM 45923-210	CDS-544	27.92	11.91	10.46	5.01	0.48	1.7	2.95	1.56	3.22	0.14	0.27	8.47
TMM 45923-211	CDS-545	28.57	12.92	10.12	4.25	0.62	1.5	2.83	1.67	2.54	0.17	0.29	10.24
TMM 45923-212	CDS-546	21.58	8.14	6.73	1.62	0.56	0.6	2.70	0.53	3.06	0.07	0.36	11.85
TMM 45923-213	CDS-554	24.75	11.27	7.25	2.56	0.77	0.9	2.84	0.90	2.83	0.00	0.01	0.52
TMM 45923-214	CDS-560	15.13	5.32	4.84	0.50	0.42	0.3	1.68	0.17	2.89	0.13	1.21	41.90
TMM 45923-215	CDS-561	18.02	8.99	8.61	1.84	0.29	0.6	3.07	0.62	2.95	0.02	0.12	3.85
TMM 45923-216	CDS-562	21.8	7.4	6.58	1.42	0.46	0.5	2.83	0.47	2.98	0.03	0.15	5.02
TMM 45923-217	CDS-563	17.26	6.89	6.03	1.06	0.48	0.5	2.11	0.32	3.29	0.18	1.18	35.84
TMM 45923-218	CDS-564	20.24	10.37	6.26	1.71	0.80	0.6	2.85	0.59	2.91	0.01	0.06	2.03
TMM 45923-219	CDS-567	20.51	10.17	7.49	2.14	0.68	0.8	2.67	0.70	3.06	0.10	0.39	12.63
TMM 45923-220	CDS-568	23.83	12.86	9.44	3.56	0.68	1.3	2.74	1.29	2.75	0.01	0.01	0.44
TMM 45923-221	CDS-569	18.01	8.06	6.77	1.30	0.54	0.4	3.24	0.44	2.95	0.04	0.29	9.02
TMM 45923-222	CDS-570	19.83	8.89	6.5	1.58	0.68	0.6	2.64	0.51	3.08	0.09	0.45	14.56
TMM 45923-223	CDS-571	17.55	8.84	6.22	1.27	0.71	0.5	2.54	0.43	2.94	0.07	0.40	13.66
TMM 45923-224	CDS-573	20.2	8.87	8.41	1.92	0.32	0.7	2.74	0.67	2.85	0.03	0.11	3.69
TMM 45923-225	CDS-575	16.63	9	8.38	1.63	0.36	0.7	2.33	0.56	2.91	0.14	0.58	19.84
TMM 45923-226	CDS-578	21.25	10.54	8.39	2.60	0.61	0.8	3.25	0.84	3.09	0.04	0.16	4.84
TMM 45923-227	CDS-579	19.87	7.79	6.59	1.55	0.53	0.6	2.58	0.46	3.39	0.14	0.81	23.94
TMM 45923-228	CDS-596	33.06	13.84	10.36	6.46	0.66	2.2	2.94	2.12	3.05	0.08	0.11	3.61
TMM 45923-229	CDS-597	49.59	21.14	16.06	17.42	0.65	8	2.18	7.53	2.31	0.47	0.14	5.85
TMM 45923-230	CDS-613	44.98	16.74	11.48	11.90	0.73	4	2.98	3.87	3.08	0.13	0.10	3.32
TMM 45923-231	CDS-622	29.75	18.17	9.57	7.57	0.85	3.2	2.36	2.31	3.27	0.89	0.90	27.68
TMM 45923-232	CDS-628	43.6	19.93	9.71	13.69	0.87	5	2.74	3.77	3.63	1.23	0.89	24.50
TMM 45923-233	CDS-629	33.38	14.13	10.31	6.84	0.68	2.6	2.63	2.18	3.15	0.42	0.51	16.33
TMM 45923-234	CDS-630	26.89	12.46	9.32	4.00	0.66	1.5	2.67	1.40	2.86	0.10	0.20	6.87
TMM 45923-235	CDS-632	28.55	12.14	11.51	6.00	0.32	2	3.00	1.78	3.36	0.22	0.36	10.76
TMM 45923-236	CDS-643	19.09	7.09	5.92	0.94	0.55	0.4	2.34	0.36	2.61	0.04	0.27	10.38
TMM 45923-237	CDS-647	37.53	16.68	8.67	5.52	0.85	1.9	2.91	2.43	2.27	0.53	0.63	21.75
TMM 45923-238	CDS-657	20.57	9.96	6.94	2.16	0.72	0.8	2.70	0.64	3.39	0.16	0.69	20.49

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-239	CDS-674	17.67	7.89	7.16	1.26	0.42	0.5	2.51	0.45	2.81	0.05	0.30	10.68
TMM 45923-240	CDS-675	24.61	10.37	9.23	2.86	0.46	1	2.86	1.05	2.71	0.05	0.15	5.11
TMM 45923-241	CDS-683	31.65	18.61	9.41	6.29	0.86	2.3	2.73	2.48	2.54	0.18	0.20	7.24
TMM 45923-242	CDS-696	28.67	12.22	9.5	3.76	0.63	1.5	2.51	1.49	2.52	0.01	0.02	0.73
TMM 45923-243	CDS-697	27.78	11.73	9.68	3.77	0.56	2.4	1.57	1.41	2.67	0.99	1.10	41.20
TMM 45923-244	CDS-698	33.33	14.12	10.38	4.20	0.68	1.6	2.63	2.19	1.92	0.59	0.70	26.79
TMM 45923-245	CDS-700	28.8	10.71	10.48	3.80	0.21	1.2	3.16	1.45	2.62	0.25	0.54	17.02
TMM 45923-246	CDS-704	25.83	11.74	9.73	3.70	0.56	1.3	2.85	1.32	2.81	0.02	0.04	1.52
TMM 45923-247	CDS-713	67.11	32.04	23.04	63.92	0.69	22	2.91	22.16	2.88	0.16	0.02	0.74
TMM 45923-248	CDS-714	57.57	28.37	10.87	20.14	0.92	8	2.52	7.94	2.54	0.06	0.02	0.72
TMM 45923-249	CDS-730	26.94	12.23	9.28	3.56	0.65	1.4	2.54	1.37	2.60	0.03	0.06	2.29
TMM 45923-250	CDS-741	39.05	15.13	12.09	10.27	0.60	3.7	2.78	3.20	3.21	0.50	0.44	13.63
TMM 45923-251	CDS-748	35.22	11.05	8.05	5.31	0.69	1.7	3.12	1.40	3.79	0.30	0.66	17.55
TMM 45923-252	CDS-750	18.88	7.58	7.17	1.37	0.32	0.5	2.73	0.46	2.98	0.04	0.24	8.19
TMM 45923-253	CDS-760	36.12	16.04	15.86	12.22	0.15	4.5	2.71	4.11	2.97	0.39	0.26	8.65
TMM 45923-254	CDS-773	39.15	15.64	11.27	9.39	0.69	3.3	2.85	3.09	3.04	0.21	0.20	6.45
TMM 45923-255	CDS-778	46.76	18.8	13.14	14.82	0.72	5.5	2.69	5.17	2.87	0.33	0.17	6.04
TMM 45923-256	CDS-784	24.73	8.64	5.84	1.90	0.74	0.7	2.71	0.56	3.40	0.14	0.69	20.25
TMM 45923-257	CDS-792	29.99	15.26	10.27	6.27	0.74	2.2	2.85	2.10	2.98	0.10	0.13	4.42
TMM 45923-258	CDS-817	29.62	12.05	10.09	5.00	0.55	1.8	2.78	1.61	3.11	0.19	0.33	10.49
TMM 45923-259	CDS-820	27.27	11.46	8.63	3.44	0.66	1.2	2.87	1.21	2.85	0.01	0.02	0.55
TMM 45923-260	CDS-827	23.79	8.64	8.54	1.93	0.15	0.7	2.75	0.79	2.46	0.09	0.30	10.86
TMM 45923-261	CDS-838	22.97	9.84	9.16	2.67	0.37	0.9	2.96	0.93	2.88	0.03	0.08	2.83
TMM 45923-262	CDS-847	53.74	29.29	14.75	26.91	0.86	9	2.99	10.39	2.59	1.39	0.40	13.35
TMM 45923-263	CDS-850	44.73	18.63	14.81	13.49	0.61	4.9	2.75	5.52	2.44	0.62	0.31	11.25
TMM 45923-264	CDS-858	43.35	19.62	14.72	15.75	0.66	6	2.63	5.60	2.81	0.40	0.19	6.65
TMM 45923-265	CDS-865	30.34	12.07	11.97	5.43	0.13	2.1	2.58	1.96	2.77	0.14	0.18	6.62
TMM 45923-266	CDS-869	33.95	13.39	9.71	6.05	0.69	2.2	2.75	1.97	3.06	0.23	0.31	10.24
TMM 45923-267	CDS-872	36.57	13.01	12.85	8.14	0.16	2.9	2.81	2.74	2.98	0.16	0.17	5.68
TMM 45923-268	CDS-880	65.2	28.65	13.04	30.88	0.89	10	3.09	10.90	2.83	0.90	0.25	8.24
TMM 45923-269	CDS-881	52.05	28.78	14.21	27.33	0.87	10	2.73	9.52	2.87	0.48	0.14	4.77
TMM 45923-270	CDS-887	16.19	7.87	6.97	1.12	0.46	0.3	3.73	0.40	2.82	0.10	0.91	24.49
TMM 45923-271	CDS-900	22.85	8.62	7.5	1.91	0.49	0.65	2.94	0.66	2.89	0.01	0.05	1.65
TMM 45923-272	CDS-903	29.24	13.03	10.29	4.99	0.61	1.7	2.94	1.75	2.85	0.05	0.09	3.08

Table 1 continued

TMM collection number	Field catalog number	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)	Eccentricity	Observed volume (ml)	Observed density (g/mm^3)	Calculated volume (ml)	Calculated density (g/mm^3)	Absolute difference between volumes	Absolute difference between density	Volume and density percentage difference
TMM 45923-273	CDS-914	34.08	19.3	13.31	10.56	0.72	4	2.64	3.92	2.70	0.08	0.06	2.08
TMM 45923-274	CDS-922	36.18	17.12	15.39	14.49	0.44	4.9	2.96	4.26	3.40	0.64	0.44	12.97
TMM 45923-275	CDS-925	32.32	13.62	11.85	8.01	0.49	2.8	2.86	2.33	3.43	0.47	0.57	16.65
TMM 45923-276	CDS-926	38.63	17.65	11.19	9.37	0.77	3.2	2.93	3.41	2.74	0.21	0.18	6.25
TMM 45923-277	CDS-930	33.94	15.29	11.63	8.13	0.65	3.1	2.62	2.70	3.01	0.40	0.39	12.90
TMM 45923-278	CDS-936	22.16	8.25	6.82	1.77	0.56	0.7	2.53	0.56	3.17	0.14	0.64	20.31
TMM 45923-279	CDS-938	17.36	6.89	6.61	1.07	0.28	0.4	2.67	0.35	3.01	0.05	0.35	11.57
TMM 45923-280	CDS-940	28.9	10.15	7.5	2.61	0.67	0.9	2.90	0.98	2.65	0.08	0.25	8.56
TMM 45923-281	CDS-942	25.74	10.32	9.84	3.28	0.30	1.8	1.82	1.17	2.80	0.63	0.98	35.03
TMM 45923-282	CDS-952	38.55	16.33	15.1	10.93	0.38	4	2.73	4.25	2.57	0.25	0.16	5.94
TMM 45923-283	CDS-959	34.73	15.5	12.72	9.85	0.57	3.5	2.81	3.06	3.22	0.44	0.40	12.47
TMM 45923-284	CDS-962	28.55	11.84	9.41	4.18	0.61	1.5	2.79	1.42	2.94	0.08	0.15	5.13
TMM 45923-285	CDS-963	27.77	12.08	9.26	4.14	0.64	1.5	2.76	1.39	2.98	0.11	0.22	7.35
TMM 45923-286	CDS-987	39.95	18.17	9.96	9.23	0.84	3.4	2.72	3.23	2.85	0.17	0.14	4.87
TMM 45923-287	CDS-997	20.34	7.81	7.17	1.40	0.40	0.5	2.81	0.51	2.76	0.01	0.05	1.88
TMM 45923-288	CDS-1000	39.8	19.46	12.27	11.35	0.78	5	2.27	4.25	2.67	0.75	0.40	14.97
TMM 45923-289	CDS-1003	53.59	30.68	14.05	28.02	0.89	10	2.80	10.33	2.71	0.33	0.09	3.24
TMM 45923-290	CDS-1004	49.84	19.61	15.63	18.37	0.60	7	2.62	6.83	2.69	0.17	0.06	2.37
TMM 45923-291	CDS-1013	19.16	8.63	7.11	1.75	0.57	0.7	2.49	0.53	3.32	0.17	0.83	24.86
TMM 45923-292	CDS-1022	33.04	12.58	10.06	5.26	0.60	1.8	2.92	1.87	2.81	0.07	0.11	3.78
TMM 45923-293	CDS-1023	37.25	18.47	9.69	9.70	0.85	3.3	2.94	2.98	3.25	0.32	0.31	9.62
TMM 45923-294	CDS-1029	20.19	10.35	9.78	3.18	0.33	1.1	2.89	0.91	3.48	0.19	0.59	16.88
TMM 45923-295	CDS-1045	64.12	24.05	13.68	25.31	0.82	9	2.81	9.44	2.68	0.44	0.13	4.64
TMM 45923-296	CDS-1054	52.28	20.04	10.31	14.79	0.86	6	2.47	4.83	3.06	1.17	0.60	19.46
TMM 45923-297	CDS-1055	30.98	11.41	11.27	5.59	0.16	2	2.80	1.78	3.14	0.22	0.34	10.89
TMM 45923-298	CDS-1056	11.77	5.07	4	0.28	0.61	0.1	2.77	0.11	2.59	0.01	0.18	6.36
TMM 45923-299	CDS-1057	26.87	12.28	11.35	3.93	0.38	1.3	3.02	1.68	2.35	0.38	0.68	22.41
TMM 45923-300	CDS-1058	53.46	26.96	13.33	26.77	0.87	9	2.97	8.60	3.11	0.40	0.14	4.50

References

Amstutz, G. C. (1958). Coprolites: a review of the literature and a study of specimens from Southern Washington. *Journal of Sedimentary Petrology, 28*, 498–508.

Bertin, L. (1958). Appareil digestif. 1248–1302 *In* GRASSE, P.P. (ed). Traite de Zoologie. (pp.1248–1302). Paris: Masson and Cie.

Buckland, W. (1829). On the discovery of coprolites, or fossil faeces, in the Lias at Lyme Regis, and in other formations. *Transactions of the Geological Society of London, 2*, 223–236.

Case, E. C. (1915). *The Permo-carboniferous red beds of North America and their vertebrate fauna* (p. 176). Washington DC: The Carnegie Institution of Washington.

Chin, K. (1996). The paleobiological implications of herbivorous dinosaur coprolites: ichnologic, petrographic, and organic geochemical investigations. PhD thesis. University of California, Santa Barbara, 162 pp.

Chin, K. (2002). Analysis of coprolites produced by carnivorous vertebrates. Paleontological Society Papers, 8, 43–50

Chin, K., Eberth, D. A., Schweitzer, M. H., Rando, T. A., Sloboda, W. J., & Horner, J. R. (2003). Remarkable preservation of undigested muscle tissue within a late Cretaceous tyrannosaurid coprolite from Alberta, Canada. *Palaios, 18*, 286–294.

Chin, K., Tokaryk, T. T., Erickson, G. M., & Calk, L. C. (1998). A king-sized theropod coprolite. *Nature, 393*, 680–682.

Cope, E. D. (1878). Descriptions of extinct Batrachia and Reptilia from the Permian formation of Texas. *Proceedings of the American Philosophical Society*, *17*, 505–530.

DiMichele, W. A., Mamay, S. H., Chaney, D. S., Hook, R. W., & Nelson, J. W. (2001). An early Permian flora with Late Permian and Mesozoic affinities from North-Central Texas. *Journal of Paleontology, 75*, 449–460.

Duffin, C. J. (1979). Coprolites: a brief review with reference to specimens from the Rhaetic Bone-Beds of England and South Wales. *Mercian Geologist, 7*, 191–204.

Fritsch, A. (1907). *Miscellanea palaeontologica, 1, Palaeozoica*. Prague: F. Rivnác.

Gilmore, B. (1992). Scroll coprolites from the Silurian of Ireland and the feeding of early vertebrates. *Palaeontology, 35*, 319–333.

Häntzschel, W., El-Baz, F., & Amstutz, G. C. (1968). Coprolites, an annotated bibliography. Memoirs of the Geological Society of America, 108, 1–132.

Hentz, T. F. (1988). Lithostratigraphy and paleoenviroments of Upper Paleozoic continental red beds, North-Central Texas: bowie (New) and Wichita (Revised) Groups. *Bureau of Economic Geology of Texas, 170*, 1–55.

Holmgren, S., & Nilsson, S. (1999). Digestive system. In Hamlett W. C. (Ed.), *Sharks, Skates, and Rays the Biology of Elasmobranch Fishes*. (pp. 144–173). Johns Hopkins University Press.

Hunt, A. P. (1992). Late Pennsylvanian coprolites from the Kinney Brick Quarry, central New Mexico with notes on the classification and utility of coprolites. *New Mexico Bureau of Mines and Mineral Resources Bulletin, 138*, 221–229.

Hunt, A. P., Chin, K., & Lockley, M. G. (1994). The palaeobiology of vertebrate coprolites. In Donovan S. K. (Ed.), The Palaeobiology of Trace Fossils. (pp.221-240). John Wiley & Sons.

Hunt, A. P., & Lucas, S. G. (2005a). A new coprolite ichnotaxon from the Early Permian ofTexas. *New Mexico Museum of Natural History and Science Bulletin, 30*, 121–122.

Hunt, A. P., & Lucas, S. G. (2005b). The origin of large vertebrate coprolites from the Early Permian of Texas. *New Mexico Museum of Natural History and Science Bulletin, 30*, 125–126.

Hunt, A. P., & Lucas, S. G. (2012). Descriptive terminology of coprolites and recent feces. *In* Hunt, A. P., Milan, J., Lucas, S. G., & Spielmann, J. A. (eds) *Vertebrate Coprolites* (pp. 153–160). *New Mexico Museum of Natural History and Science Bulletin*, 57, 387.

Hunt, A. P., Lucas, S. G., & Lockley, M. G. (1998). Taxonomy and stratigraphic and facies significance of vertebrate coprolites of the Upper Triassic Chinle Group, Western United States. *Ichnos, 5*, 225–234.

Hunt, A. P., Lucas, S. G., & Spielmann, J. A. (2005a). Early Permian vertebrate coprolites from North-Central New Mexico with description of a new ichnogenus. *New Mexico Museum of Natural History and Science Bulletin, 31*, 39–42.

Hunt, A. P., Lucas, S. G., & Spielmann, J. A. (2005b). Biochronology of Early Permian vertebrate coprolites of the American Southwest. *New Mexico Museum of Natural History and Science Bulletin, 31*, 43–45.

Hunt, A. P., Lucas, S. G., Spielmann, J. A., & Lerner, A. J. (2007). A review of vertebrate coprolites of the Triassic with descriptions of New Mesozoic ichnotaxa. *New Mexico Museum of Natural History and Science Bulletin, 41*, 88–107.

Hunt, A. P., Milan, J., Lucas, S. G., & Spielmann, J. A. (2012). Vertebrate Coprolites. *New Mexico Museum of Natural History & Science Bulletin, 57*, 1–387.

Jain, S. L. (1983). Spirally coiled 'coprolites' from the Upper Triassic Maleri Formation, India. *Palaeontology, 26*, 813–829.

Johnson, G. D. (1992). Early Permian vertebrate microfossils from Archer City Bone Bed 3, Archer County, Texas. *Journal of Vertebrate Paleontolgy Abstracts, 12*, 35A–36A.

Johnson, G. D. (1996). Vertebrate microfossils from the Lueders Formation, Albany Group, and the faunal transition from the Wichita Group Into the Clear Fork Group, Lower Permian of Texas. *Modern Geology, 20*, 371–382.

Johnson, G. D. (1999). Dentitions of Late Palaeozoic *Orthacanthus* species and new species of *Xenacanthus* (Condrichthyes: xenacanthiformes) From North America. *Acta Geolological Polonica, 49*, 215–266.

Labandeira, C. C., & Allen, E. G. (2007). Minimal insect herbivory for the Lower Permian coprolite bone bed site of north-central Texas, USA, and comparison to other Late Paleozoic floras. *Palaeogeography, Palaeoclimatology, Palaeoecology, 247*, 197–219.

Mcallister, J. A. (1985). Reevaluation of the formation of spiral coprolites. *University of Kansas Paleontological Contributions Papers*, 114, 1–12

Mcallister, J. A. (1987). Phylogenetic distribution and morphological reassessment of the intestines of fossil and modern fishes. *Zoologische Jahrbücher, jena, Abteilung für Anatomie, 115*, 281–294.

Neumayer, L. (1904). Die Koprolithen des Perms von Texas. *Palaeontographica, 51*, 121–128.

Northwood, C. (2005). Early Triassic coprolites from Australia and their palaeobiological significance. *Palaeontology, 48*, 49–68.

Olson, E. C. (1966). Community evolution of the origin of mammals. *Ecology, 47*, 291–302.

Parker, T. J. (1885). On the intestinal spiral valve in the genus *Raja*. *Transactions of the Zoological Society of London, 11*, 49–61.

Read, C. B., & Mamay, S. H. (1964). Upper Paleozoic floral zones and floral provinces of the United States. *U.S. Geological Survey Professional Papers, 454 K*, 1–35.

Romer, A. S. (1928). Vertebrate faunal horizons in the Texas Permo-Carboniferous red beds. *University of Texas Bulletin*, *2801*, 67–108.

Romer, A. S., & Parsons, T. S. (1986). *The Vertebrate Body* (6th ed.). Philidelphia: Sanders College Publishing.

Romer, A. S., & Price, L. I. (1940). Review of the pelycosauria. *Geological Society of America Special Papers*, 28, 1–538

Sander, P. M. (1987). Taphonomy of the Lower Permian Geraldine Bone Bed in Archer County, Texas. *Palaeogeography, Palaeoclimatology, Palaeoecology, 61*, 221–236.

Sander, P. M. (1989). Early Permian depositional environments and pond bone beds in central Archer County, Texas. *Palaeogeography, Palaeoclimatology, Palaeoecology, 69*, 1–21.

Schneider, J. W. (1996). Xenacanth teeth: a key for taxonomy and biostratigraphy. *Modern Geology, 20*, 321–340.

Stewart, J. D. (1978). Enterospirae (fossil intestines) from the Upper Cretaceous Niobrara Formation of Western Kansas. *University of Kansas Paleontological Contributions Papers*, 89, 9–16

Thulborn, R. A. (1991). Morphology, preservation and palaeobiological significance of dinosaur coprolites. *Palaeogeography, Palaeoclimatology, Palaeoecology, 83*, 341–366.

Wardlaw, B. R., Davydov, V., & Gradstein, F. M. (2004). The Permian Period. *In* Gradstein, Ogg, F. M., Smith, J. G. and Smith, A. G. (eds) *A Geologic Time Scale*. (pp. 249–270) Cambridge: Cambridge University Press.

Williams, M. E. (1972). The origin of spiral coprolites. *University of Kansas Paleontological Contribution Papers*, 59, 1–12

Zidek, J. (1980). *Acanthodes lundi*, new species (Acanthodii), and associated coprolites from uppermost Mississippian Heath Formation of central Montana. *Annals of the Carnegie Museum, 49*, 49–78.