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A Partial Mandible in the Stomach Contents of a *Tyrannosaurus rex*

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Abstract

A partial mandible was discovered in a mass of fossilized stomach matrix near an incomplete *Tyrannosaurus rex* skeleton found in Dawson County, Montana, in 2009. The dissection of the *T. rex* stomach contents revealed a partial mandible with a secodont, two-cusped last molar tooth in a damaged socket. The bone of the mandible was structurally damaged, but it was only mildly attacked by stomach acids, strongly suggesting the *T. rex* died shortly after eating the animal. Electron microscope analysis of the tooth enamel remaining on the partly digested specimen indicated it belonged to a small mammal. The stomach of the dinosaur was filled with fossilized mud and sand that protected the mammal's jaw from further digestion. This also showed clear evidence that the *T. rex* died by drowning. In addition, the electron microscope studies of the teeth suggest a slower-than-modern-day development of the mammalian dental enamel prisms.

Introduction

Dinosaurs have been explained, nearly exclusively, within the parameters of evolutionary paleontology. However, according to the biblical Creation model, mankind would have seen and interacted with dinosaurs. Therefore, within man's own history, we should be able to learn much about these creatures; surpassing the current offerings of evolutionary paleontology. Items like habitat, instinctual habits, predator/prey relations, etc. should be recoverable within man's written and oral history.

Obviously, seeking out man's eyewitness accounts of dinosaurs in our history is an avenue of study that evolutionary paleontologists would never consider. Their errant presupposition of dinosaur extinction 64 million years, before the origin of humans, precludes them from searching for historical accounts. This is a clear 'blind spot' in evolutionary research, and a clear advantage for Creation researchers.

In particular, this project was initiated by the idea of searching for Mammoth remains (assuming North American discovery) in dinosaur coprolite or, even better, fossilized stomach contents. This idea stemmed from multiple historic references that seemed to point to a dinosaur/elephant-kind predator-prey relationship. However, due to the rarity of stomach contents of carnivorous dinosaurs and the evolutionary grip on

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recoverable dinosaur remains, it was not a foregone conclusion that this study could ever materialize.

The reach of the young-earth Creation community has grown, and in direct relation to this project, the Glendive Dinosaur and Fossil Museum has made significant inroads to position itself to have access to high-quality dinosaur discoveries. This growth in the young-earth community has enabled creationists, using creationist models, to do their own research in a field dominated by well-funded evolutionists.

Our excavations did not find consumed mammoth remains, but it did find mammalian remains in the very first excavation. And even though evolutionists have grudgingly accepted mammalian and dinosaurian co-existence in recent years, they have not always done so. The evidence, which revealed itself so quickly in this study, suggests that a biblical starting point would have advanced dinosaurian knowledge by decades. This gives strong support for the view that adhering to the biblical time frame would greatly expedite scientific discovery.

The research also yielded unexpected evidence. The find suggests new ideas about animal development, and perhaps even animal longevity in a pre-Flood environment. This appears to be the first report of this information. We suggest this evidence represents new ways of thinking in which further research will need to be done to develop into testable hypotheses.

The Discovery

In 2009, the incomplete remains of a *Tyrannosaurus rex* were excavated from a plot of land in Dawson County, Montana. The legal description of the find is the south half of Section 8, T 14 N, R 56 E, Dawson County, Montana.

The geology of this area has a “Badland” designation. It consists of very steep, nearly barren areas characterized by nearly vertical escarpments, narrow ridges, isolated buttes, and deeply entrenched coulees. These areas were formed by the active geological erosion of soft, multicolored sedimentary beds of loamy sand, sandy loam, silt loam, clay loam, and silty clay. Slopes range from 15% to more than 100%. The subject fossil find was on the ridge where Blanchard, Dast, Dimyaw, and Lambert soils are found. The Lambert complexes contain steep slopes (8 to 45%) and shallow soils ranging from 10 to 20 inches in depth with cool season grasses. It also contains little bluestem (*Schizachyrium scoparium*), which could represent up to 30% of the plant community.

The little bluestem can exist in soils ranging from pH 5.0 to pH 8.4 (USDA Plants Database). Therefore, the soil is probably somewhere between pH 5 and pH 8.4. Overly acidic soil is detrimental to fossilization, whereas slightly alkaline environments are good for bone survival (Farlow and Argast, 2006).

Parts of the fossilized remains were four variously sized pieces of stomach contents, or possibly coprolites, listed (C) in Figure 1. Figure 1 is a map of the *T. rex* site and indicates the location of the pieces of stomach contents/coprolites in relation to the rest of the skeletal remains A and B. Relative distances between the three areas are listed in this triangle-shaped discovery. The easternmost piece in C (arrow) is seen below the largest piece and is an irregularly shaped mass in Figure 2. It measures 21 cm long × 13.5 cm high × 14 cm deep across the center. This piece is the focus of our research.

A small section of this irregular piece revealed a surface anomaly uncharacteristic of the rest of the remnant. Figure 3 shows it was approximately 25 mm long, triangular, and lighter in color than the rest of the mass. This triangular inclusion in the fossilized mass was carefully removed from the solid matrix using a Micro-Jack air scribe. It was discovered to be a partial right side of a mandible and a two-cusped, secondont-type molar tooth in its eroded socket (Figure 4).

Gut Contents or Coprolite?

It is important to understand that stomach contents of large dinosaurs are rare.

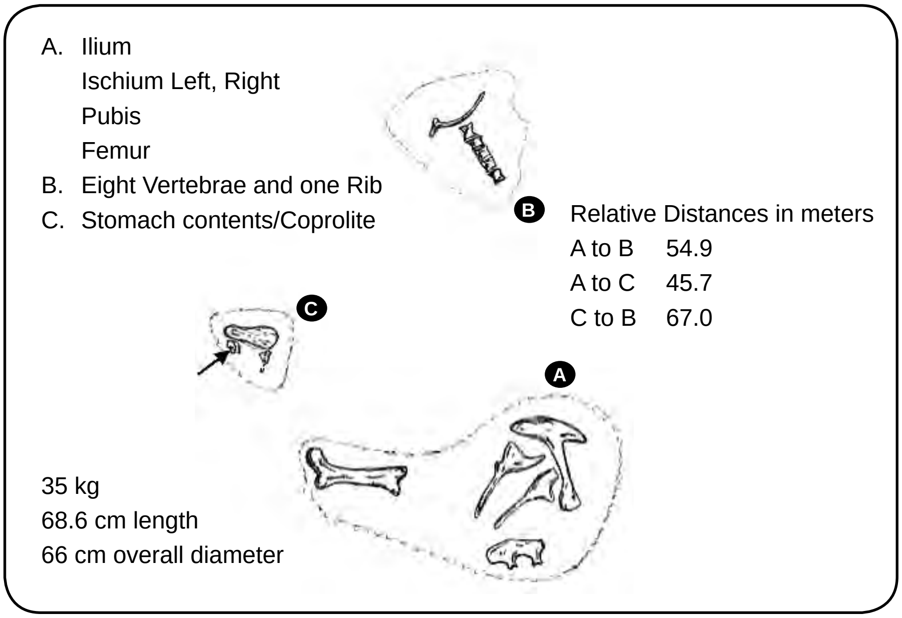

Figure 1. Map location of *Tyrannosaurus rex* excavation (August, 2009).

Figure 2. Stomach contents/coprolite.

Figure 3. Triangular object of interest in mass.

Hone and Rauhut (2010, p. 236) stated,

> There are a number of well-preserved and articulated large theropod specimens that are known from around the world (e.g. *Allosaurus*, *Albertosaurus* and *Tarbosaurus*). It is rare for both large and small theropods to be preserved with bony stomach contents of previous meals, although a few are known, and in these, bones of considerably smaller prey than the predator seem to have been swallowed whole (e.g. *Baryonx*, *Compsognathus* and *Sinosauropteryx*).

They also concluded that there is no definitive evidence that these predators regularly ingested bone, which also makes this discovery important because bone was found in the remains.

In a landmark investigation of the gut contents of a Cretaceous tyrannosaurid, Varricchio (2001) described a partial skeleton of *Daspletosaurus sp.* from the upper Cretaceous (Campanian) in the Two Medicine Formation of Western Montana. This specimen yielded the first gut contents reported for a tyrannosaurid. There were also some vertebrae, a fragmentary dentary from a juvenile hadrosaur, and other hadrosaur elements.

All of these tyrannosaurid and hadrosaur bones fit within a 20-cm–thick blocky green claystone. The length and width of the discovery site was calculated from his map to be approximately 4.4 by 3.1 m. Varricchio (2001) suggests that these remains were deposited in a floodplain pond "quiet ephemeral waters" based on the presence of gastropods, *Physa*, and small bivalves.

The obvious difference between the present discovery and that of Varricchio's specimen is the slope, ridges, buttes, coulees, and escarpments and active geological erosion that characterize our area. It is extremely steep in places, and the downward movement of these bones is due to the topography. Remarkably, the *T. rex* remains stayed within a periphery of approximately 1300 square meters.

Important Questions

The first question when finding a matrix of fecal substances or digested materials in association with the skeletal parts of a dinosaur is: How close is the matrix to the bones?

The second question concerning our four solid conglomerate pieces of animal origin should be: Are the masses coprolites or pieces of stomach contents? It is

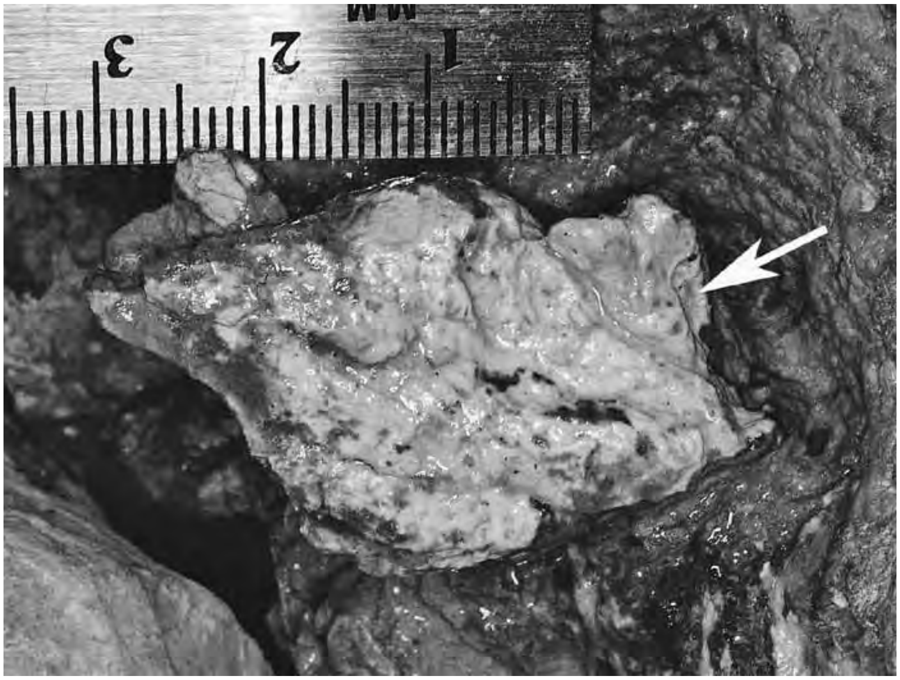

Figure 4. Lighter colored partial mandible and secodont lower molar are exposed in fossilized darker matrix. Note partial (damaged) mesial root (arrow).

important to note that the odds against this being stomach contents were very high with many more coprolites being found than gut contents (Varrichio, 2001).

It must be noted that Location C, the site of the contents/coprolite, was about 46 meters from the right femur. Therefore, do the waste products belong to the same theropod as the femur, and does a longer distance from the bones weaken their relationship? The admitted answer to the last question is yes. However, there are mitigating factors that affect the answer.

In 1995, a very large theropod coprolite (44 cm x 13 cm x 16 cm) was discovered by Sloboda and Tokaryk in Saskatchewan, Canada (Chin et al., 1998). It was found about 2 km south of the associated *T. rex* bones from a slightly higher elevation in the Frenchman Formation near the town of Eastend. We emphasize that these bones were over one mile away from the coprolite in question.

In their conclusions, the distance argument lost some of its persuasive ability due to four facts. The first is size of the mass, which is 44 cm long. The second is its phosphatic composition (Chin et al., 1998). The most diagnostic criterion of a carnivore coprolite is its phosphorous content (Hunt et al, 1994). Since the earth's crustal rocks normally contain only 0.1% phosphorus by weight (Beatty, 2001), concentrated phosphatic masses (higher than 0.1%) usually indicate a biotic mass such as a coprolite.

Third, Chin et al. (1998) point out that the configuration of the mass is consistent with irregular fecal deposits of very large animals. Fourth, the matrix contained 30% to 50% bone fragments, and this supported the contention that it was a fecally aggregated mass, and not a group of bones that just floated together. Therefore, the giant mass was confirmed as waste belonging to a *Tyrannosaurus rex*. In their deliberation about attributing the mass to a *T. rex*, Chin et al. (1998, p. 680) write:

> A few fossil faeces have been ascribed to herbivorous dinosaurs, but it is more difficult to identify coprolites produced by theropods because other carnivorous taxa coexisted with dinosaurs and most faeces are taxonomically ambiguous.

In other examples, two phosphatic coprolites, from Belgium (Bertrand, 1903) and India respectively (Matley, 1939; Jain, 1989), were close to 20 cm long and 10 cm wide and were accredited to dinosaurs but could have come from crocodilians or fish. Therefore, the definition of a phosphatic coprolite is crucial to our understanding of the differences between stomach and fecal material. Chin (2002, p. 43) explains that "significant concentrations of calcium and phosphorus in bone and flesh often favor the preservation of carnivore feces by providing autochthonous sources of constituents that can come from permineralizing calcium phosphates."

Therefore, it must be emphasized that the groundmass of most coprolites is phosphatic. Examining this closer, we find that the fossil record has more coprolites produced by carnivores than herbivores. This disparity may reflect that feces, generated by diets of bone and flesh, contain chemical constituents that precipitate out under some conditions as permineralizing phosphates. Even though the exact identity of a coprolite producer often remains unknown, the fossil feces can provide perspectives on prey selection, digestive efficiency, and the presence of previously unknown taxa in an ecosystem (Chin, 2002). All of these are very relevant to our specimen.

In fact, direct evidence, as explained by Hone and Rauhut (2010), can be ascertained from predator-damaged bones, coprolites, and preserved stomach contents. As an example, by using coprolites as the source, Chure et al. (2000) implied that theropods were not habitual bone eaters because of the rarity of bones that display obvious damage caused by theropod teeth. Tooth marks can be diagnostic when matched with actual theropod teeth. Other paleontologists have agreed with this conclusion (e.g., Hone and Rauhut, 2010).

Jacobsen (1998) examined 339 ceratopsid and 339 hadrosaur bones and found tooth marks on only 14% of the hadrosaurs and 5% of the ceratopsids. Jacobsen (1998) concluded the frequency of tooth marks on tyrannosaurid bones was lower than on the skeletal remains of the herbivores. But, we do see that theropods were eaten by other theropods.

Preservation

Even if the bones are not too damaged by the chewing process, a question still remains regarding the effect of stomach acids on the preservation of the bones. Would not the bone matter be digested, given a normal length of time in the stomach? It has been reported that in large living crocodiles that consume bony animals no recognizable bone fragments are passed from the body (Andrews and Fernandez-Jalvo, 1998).

This complete digestion is due to stomach acids. So, how can we explain the safe transport of our partial mandible through the digestive process of the tyrannosaurid? Due to the length of their gut, large theropods should have had long digestive times (Hone and Rauhut, 2010).

However, if the theropod died soon after feeding, then what effect would this have on the bony stomach contents? It has been determined in human digestion that a stomach would empty its contents four to six hours after a meal, under normal circumstances. Therefore, if a digestive system is filled with food during an autopsy, then it is reasonable to conclude death occurred relatively soon after a meal (Hess and Orthmann, 2010).

If we apply this to animals, though there would be some variation, we could safely assume that the discovery of undigested contents would imply that the creature did not die weeks after its last meal. Instead, the time frame would probably be less than a day.

Figure 5. Lateral view of mandible and last molar (entire mesial root lost in preparation; mesial, right; distal, left). No alveolar buccal bone remains over the molar root.

Figure 4 reveals the exposed partial mandible (ramus) and molar tooth as seen from the buccal, or cheek, side. In this picture, we notice that the partial mandible and molar tooth had not yet been completely separated from each other or from the stony matrix. This suggests incomplete digestion.

Mandible and Molar Tooth

Figures 5–10 show various views of the partial mandible and lower molar tooth that are pertinent to our study. Table I provides the measurements of the partial mandible.

In describing the mandible, it should be noted that it appears that the condyle has been displaced anteriorly by some molding force inside the *T. rex* stomach. We conclude this because there is no microscopic evidence of cracking or any break at its base, where it meets the main upper section of the ramus. If this is the true position of the condyle, it is very unusual.

Figure 6. Lingual side of mandible without molar tooth (anterior, left; posterior, right). Some fossilized matrix protrudes (upper right) and still adheres to condyle area.

There also appears to be some flattening on the upper mesial surface of the condyle. The posterior surface of

Table I. Measurements of Mandible and Molar[1,2]

1.	Ramus Height	32.30
2.	Ramus width (A-P)	24.27
3.	Ramus width (B-L)	10.21
4.	Body width (B-L)	8.58
5.	Crown length (M-D)	8.52
6.	Crown width (B-L)	2.27
7.	Tooth height	11.06
8.	Root length	7.28
9.	Crown height	3.78
10.	Root width (B-L)	2.55
11.	Root width (M-D)	unable to measure due to loss of mesial root

[1] Measurements are millimeters

[2] B-L =bucco-lingual; A-P = antero-posterior; M-D = mesiodistal

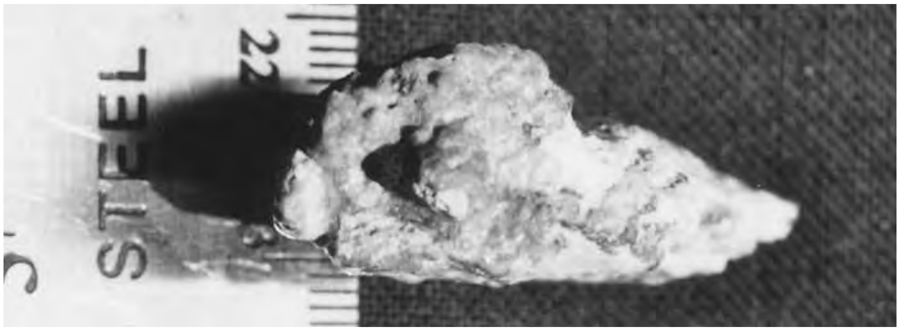

Figure 7. Superior view of mandible without molar (anterior, right; posterior, left; buccal, lower; lingual, upper—mm scale).

Figure 8. Inferior view of mandible and gonial angle (anterior, left; posterior, right; buccal, lower; lingual, upper—mm scale)

the ramus has been sheared off, probably by the *T. rex* biting motions, but no discernible tooth marks are seen on this surface of the bone. The posterior section of the condyle could have been chewed off.

There is a depression on the lateral surface of the ramus below the eroded position of the coronoid process. This seems to be a likely attachment area for the temporalis muscle. However, the medial portion of the mandible is

Figure 9. Buccal view of molar (mesial, right; distal, left). Distal cusp joined to mesial after fracture.

Figure 10. Occlusal view of molar (mesial, right; distal, left).

quite damaged, with some matrix still attached to the superior surface. It had to be left intact for fear of breaking of the entire condyle. There is a hint of the mandibular foramen just below the attached stomach matrix. Finally, on the sheared-off posterior surface, there is a brownish, hard, irregularly shaped 5 x 4-mm area that could be fossilized marrow. No attempt was made to drill into this brownish area.

The molar is a last molar, M2 or M3, and has almost no occlusal, or biting surface, wear. It appears as if it were in the process of eruption. This indicates it probably belonged to a young animal.

Energy Dispersive X-Ray

Energy Dispersive X-Ray (EDS) analysis was performed on all samples represented for determination of chemical composition. The analysis was performed on an initial qualitative basis for the purpose of elemental identification only. All samples were analyzed in their rough, untouched bulk form with no physical preparation except a carbon coating and a gold/palladium alloy coating for SEM imaging.

We present the physical elemental findings as an initial observation only. This qualitative analysis was done with the detector and calibrated against known standards. The system used these physical standards and not software-based theoretical assumptions for identification of the elements. Since the analysis was qualitative, the number of counts and the heights of the lines that identify the elements are subject to a number of parameters, which determine the ability of the line in question to be excited.

While some elements that are present in the sample have an effect on the ability of x-rays to leave the sample and be detected, there are other factors that play a role in the ability of the x-rays to escape the surface. The analysis was performed in a Hitachi S3400-N SEM (Hitachi High Technologies, California, USA) with a Bruker Analytical EDS system (Princeton, New Jersey, USA). To provide a more conclusive observation of elemental constituents, these samples would require further handling and polishing to provide a more accurate qualitative and subsequently quantitative x-ray microanalysis.

Molar and Bone EDS Analysis

Distal Cusp of molar

Figure 11 represents the EDS analysis of the enamel of the distal cusp, the hypoconid. This cusp could be any of three cusps of a talonid in a tribosphenic lower molar, but since there is no talonid basin and only two cusps, and this does not appear to be a tribosphenic molar, we will tentatively refer to it as the hypoconid. The analysis of this cusp indicates the presence of Ca, Na, Al, and Si within the sample. ANOVA analysis shows all peaks represented are statistically significant (p ≥ 95%). The presence of these elements in the enamel is not unusual. However, Phosphorus (P) is missing in

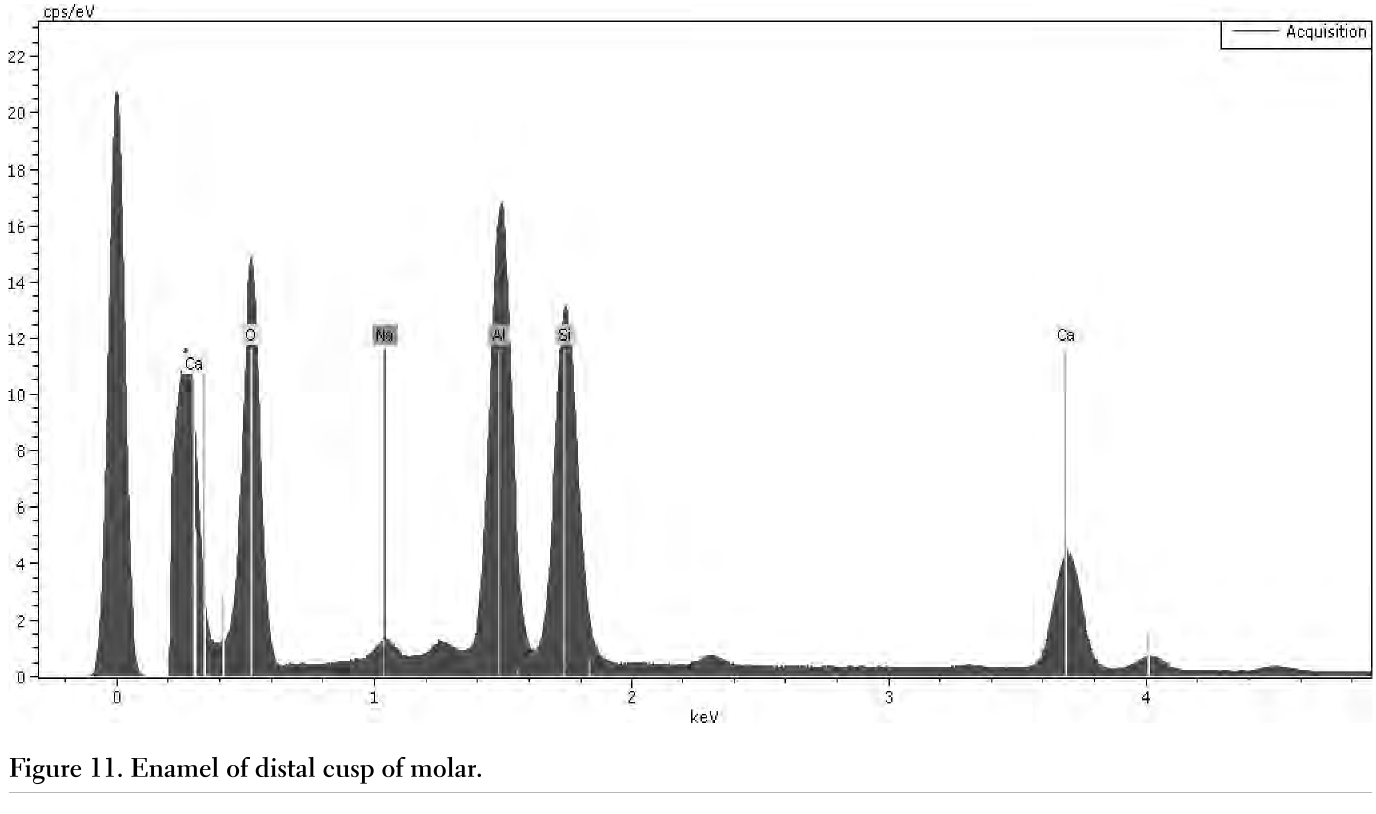

Figure 11. Enamel of distal cusp of molar.

the phosphate portion of the enamel crystal, which is unusual.

Fully formed enamel is the most highly mineralized extracellular matrix known, consisting of approximately 96% minerals and 4% organic material and water. The inorganic component consists almost entirely of calcium phosphate minerals in the form of apatite. Apatites in enamel are in a crystalline (rather than an amorphous) form.

The formula for the inorganic portion called hydroxyapatite is $Ca_{10}(PO_4)_6(OH)_2$. There are also trace elements in enamel, such as sodium and aluminum. Figure 12 and Figure 13 represent elemental analyses of two separate regions (A and B) on the buccal bony surface of the ramus of the mandible. Again the presence of Ca, Na, Al, and Si is observed. These findings were consistent with that of the

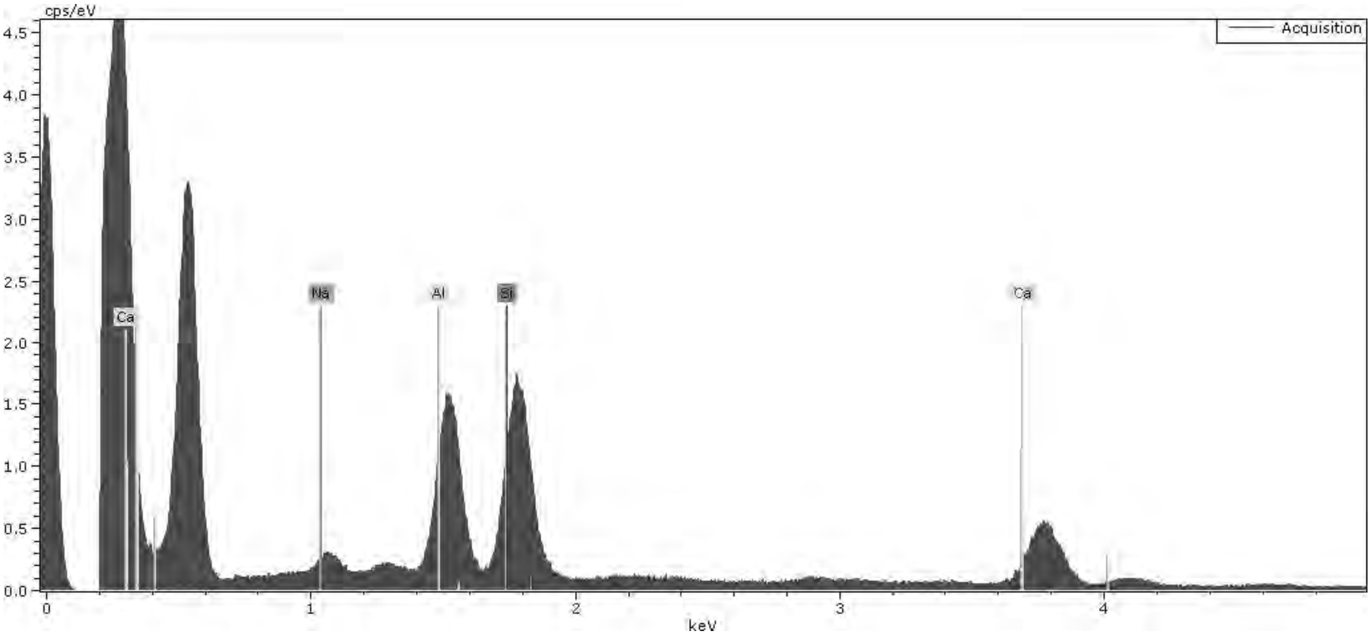

Figure 12. Lateral surface of ramus of mandible, Location A.

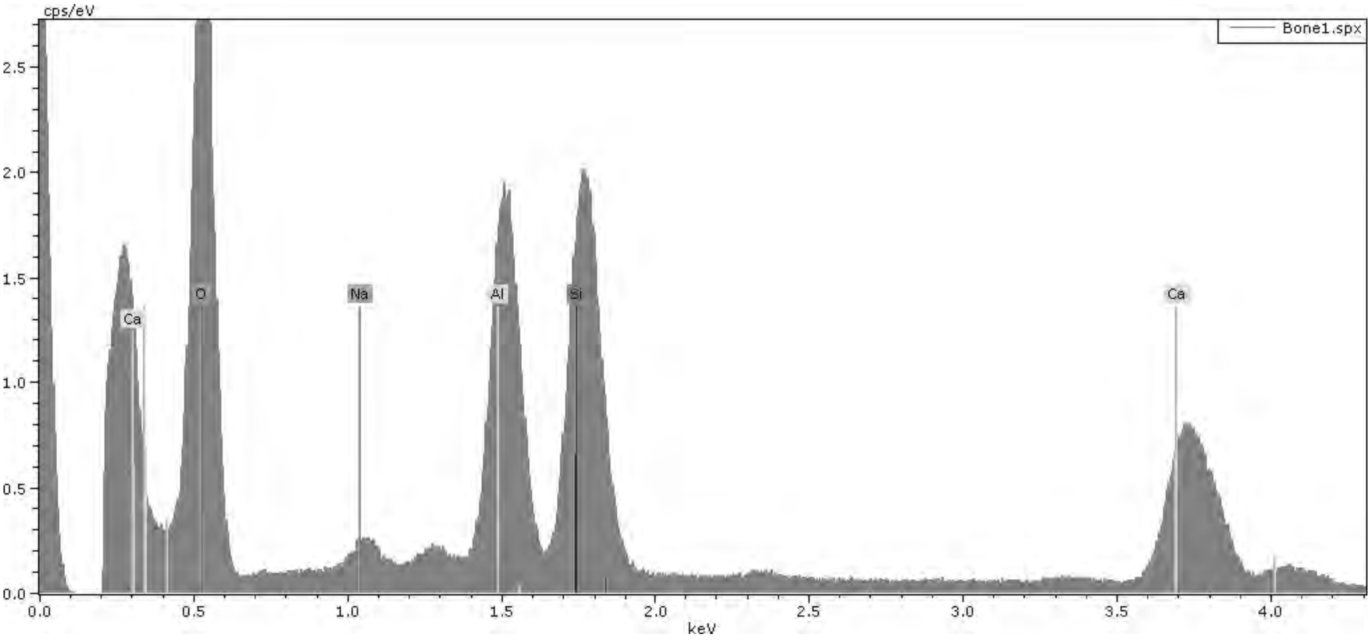

Figure 13. Lateral surface of ramus of mandible, Location B.

molar enamel. Again, ANOVA analysis found that all peaks represented are statistically valid ($p \geq 95\%$).

Figure 14 shows an overlay between Figures 12 and 13. Slight variations in the positions of the subsequent peaks are most likely due to the variations in topography within the analytical site.

Figure 15 presents a composite overlay of all three figures, 12, 13, and 14, to show the similarities between analytical composition. These would be the tooth enamel and both bony surfaces A and B. It should be noted that in this graph, while the samples were not scaled in comparison to one another, the differences in relative counts/sec are based on the topography of the individual samples relative to the detector and its placement. There is no phosphorous (P) on these surfaces.

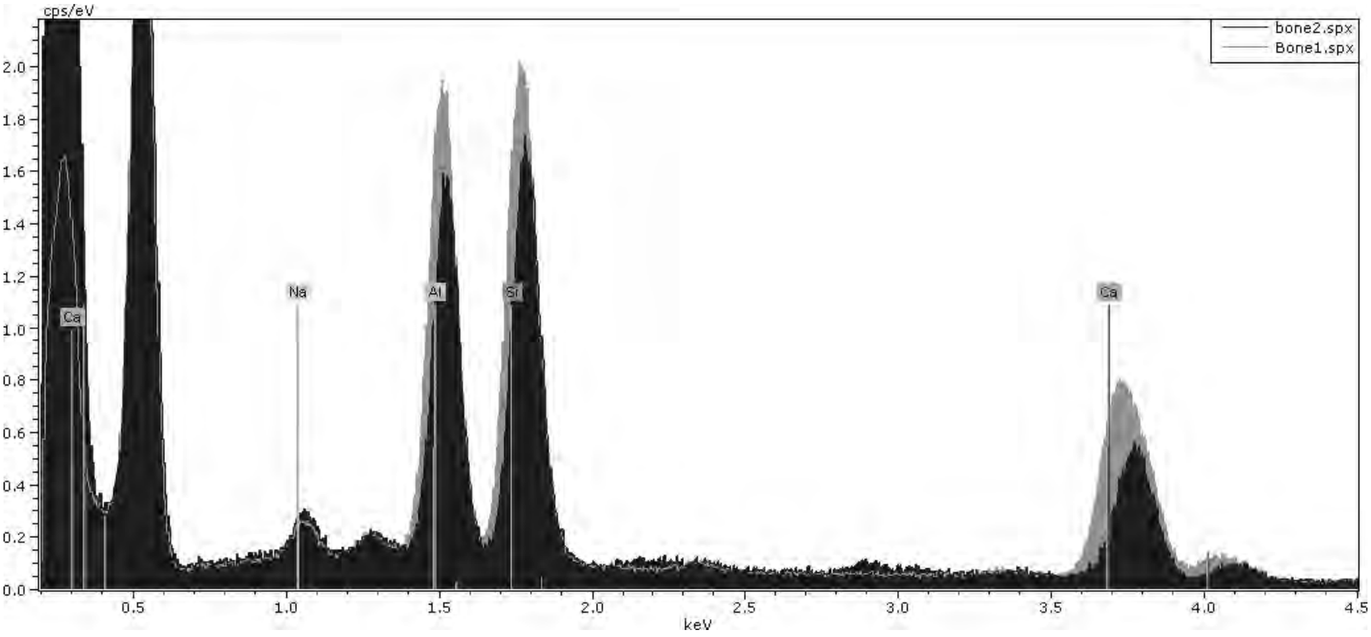

Figure 14. Both bony locations A and B on lateral surface of ramus.

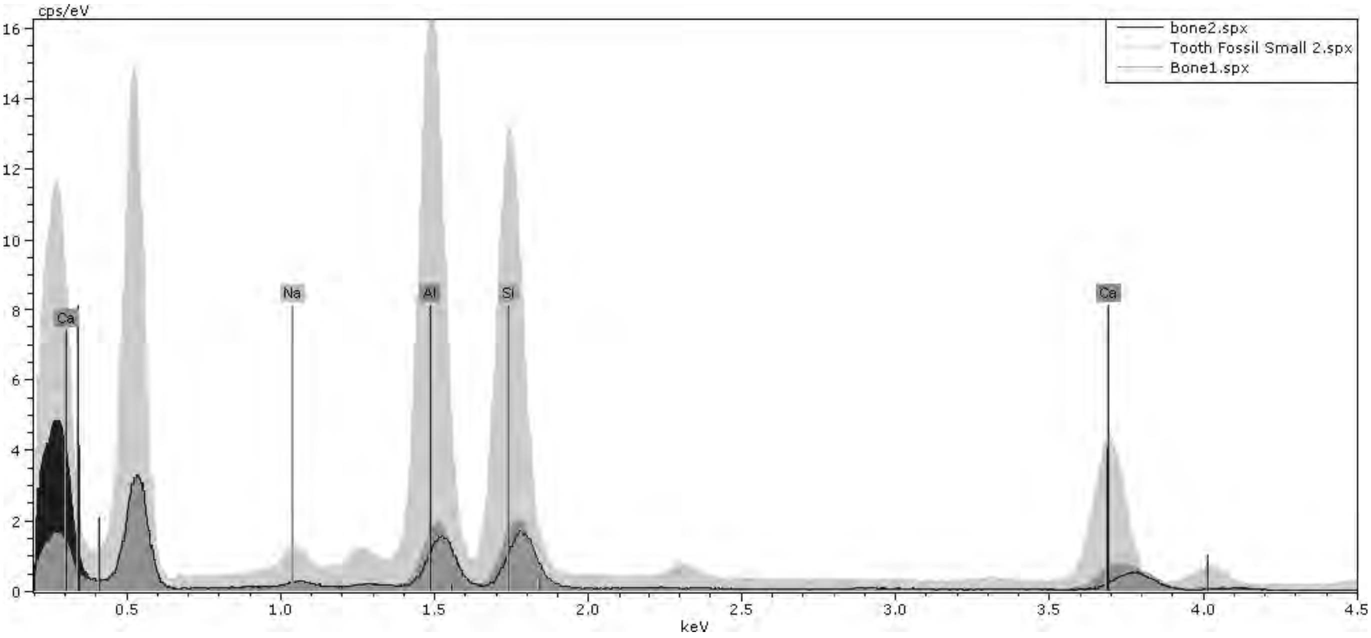

Figure 15. Composite of Figures 12, 13, and 14.

In Figure 16, a portion of the fossilized stomach matrix was analyzed from two individual locations around the location of the ramus of the mandible. Again, a qualitative EDS analysis shows that the chemical footprint is virtually identical to that of the bone and tooth represented in Figures 11 through 15. The only addition that is observed here is that there is a decrease in Al and the addition of Mg. While Fe is noted in this analysis, ANOVA analysis did not determine that its represented peak was statistically significant ($p < 95\%$). The presence of Mg may be due to the surrounding environment and/or the substitution of Mg for some of the Ca (Kohn et al., 1999). Note once again the absence of P.

Figure 17 represents the qualitative analysis of a fragment of bone taken

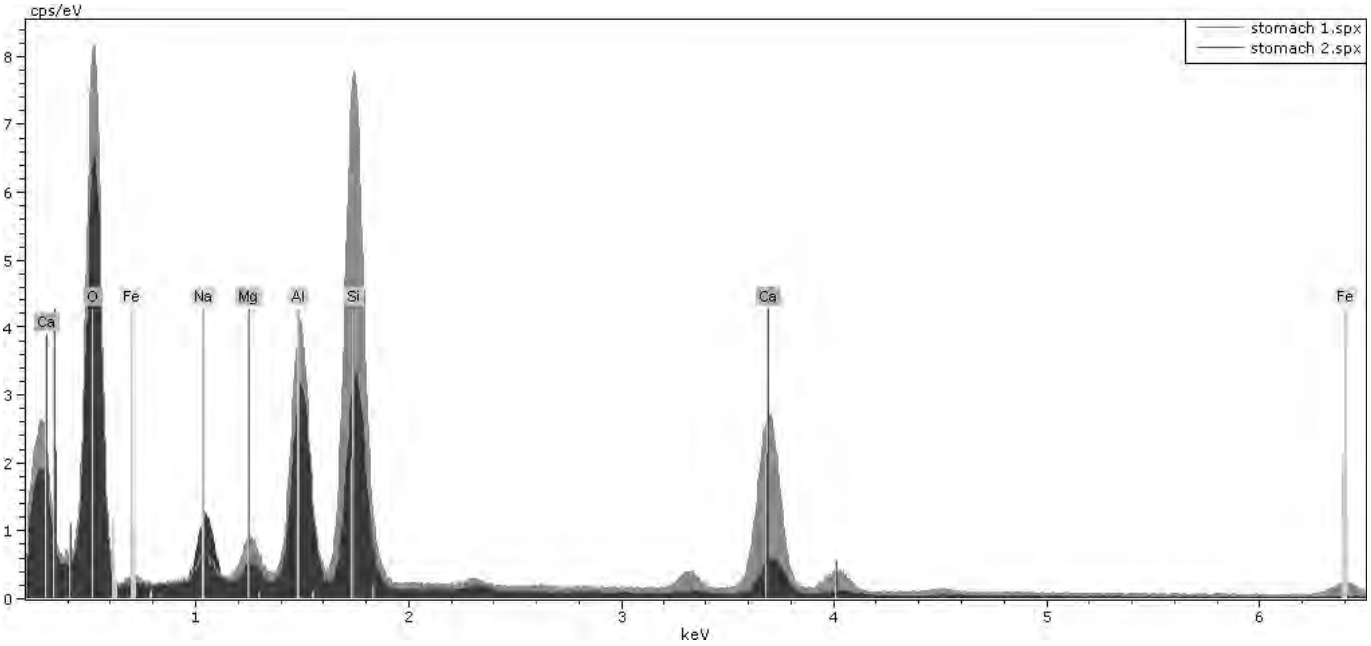

Figure 16. Fossilized matrix around bony matrix in two locations.

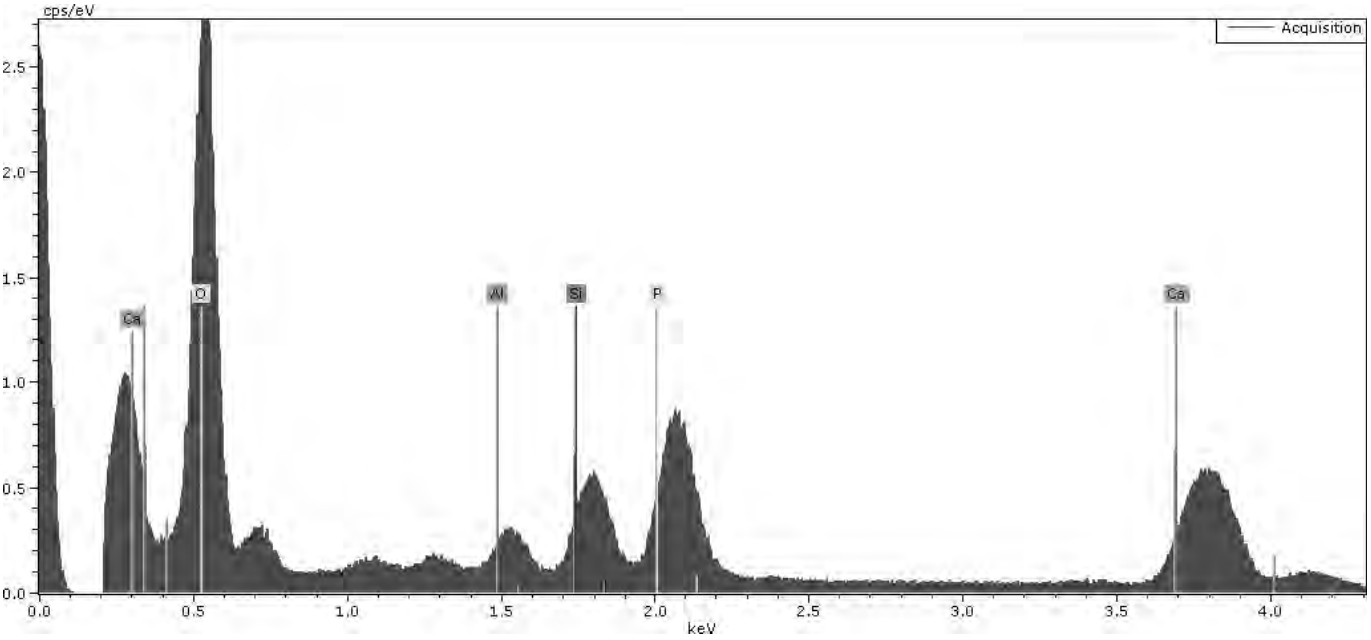

Figure 17. Fragment of right femur of *Tyrannosaurus rex.*

from the *Tyrannosaurus rex* right femur, found at location A in the Figure 1 map. The usual presence of Ca, Al, and Si are seen in this analysis, but there are two new occurrences: the absence of Na and the presence of P. Note that this is the first time P has been present and Na absent. As noted above, the phosphate (PO_4^{3-}) component of teeth and bone is a major part of the hydroxyapatite structure. Furthermore this sample was found approximately 45 meters from the stomach contents.

Figure 18 presents a composite overlay of two locations of the three observed on the *T. rex* bone. It is noted that the chemical composition of both locations are virtually identical, with the exception of the count/sec ratio due to topographical variations within the sample.

Analysis of Results

Are the elements in the enamel, mandibular bone, and femur bone indigenous to these biological entities, or are they the result a process called diagenesis? Diagenesis is the physical, chemical, and biological environmental processes that can modify an organic object's original chemical and/or structural properties. Molleson (1990, p.347) stated:

> Concentrations of certain elements in fossils can be very different from their initial concentration in bone. This may be the result of either a high concentration of these elements in the burial environments or due to preferential deposition of the elements into the bone … Apatite is host to many substitutions by cations, anions, and anionic radicals that resemble its normal constituents in size and charge.

Even teeth are not immune to diagenetic processes. For example, Kohn et al. (1999) state that apatite crystals in enamel are not immune to chemical alteration, despite enamel's lower original organic content and porosity.

Also, it is crucial to have some understanding of the effects of the digestive process of the *T. rex* stomach acids and to understand the effects of reposing in mineral-laden soil for thousands of years. Certainly these combinations could be the reason for the elemental peaks seen in the above figures.

The first questions are: Why is Na not present in the *T. rex* femur, and why is there no P in both the tooth and mammalian bone? Parker et al. (1974, p. 1317) provide some data relevant to that question.

> In fossil bone and dentine the sodium content is much lower (0.15–0.41 wt.%) than in corresponding modern samples while there appears to be no significant difference between modern and fossil enamel in most instances. The lowered sodium content in fossil material appears to be attributable to diagenetic removal. The physical properties of the bone have a strong influence on the amount of sodium removed.

Lambert et al. (1985, p. 477) added that "calcium and sodium may be lost through leaching but may be useful in the dietary context."

Dumont et al. (2009) found Na in the fossil bone apatite in a femur of a sauropod from Tanzania in their EDX maps. So, we conclude it is not ideal, but neither is it unreasonable, that no Na is found in the *T. rex* femur.

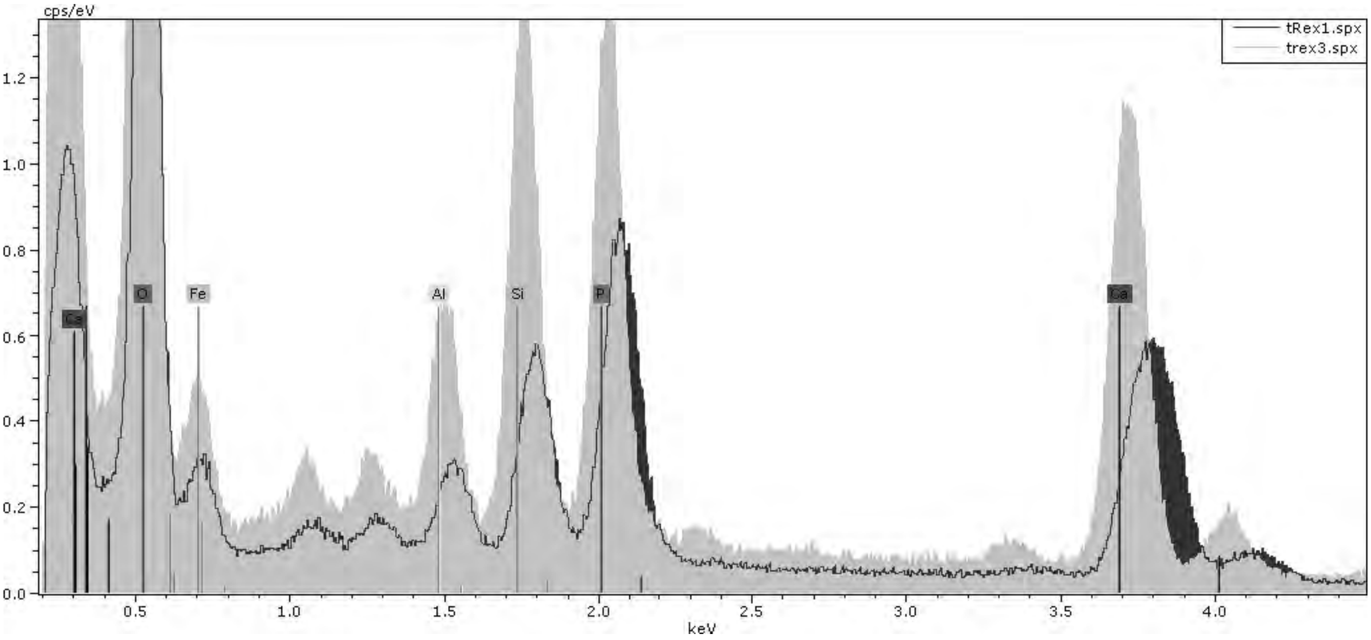

Figure 18. Composite of two of the three locations observed on the *Tyrannosaurus rex* right femur.

Another factor that enhances chemical or bacterial diagenesis is the effect of chewing by the gigantic *T.rex* jaws on the bones of this small animal. Chewing opens up more surface area to the diagenetic processes and allows it to work faster.

Although this bone must have been chewed some, considering the loss of almost the entire left side of the mandible, it is not unreasonable to assume it was swallowed quickly or gulped, because there are no characteristic *T.rex* tooth marks on the small mammal mandible. Basically, it just appears damaged on its surface.

What happened to the phosphate in the mammal tooth and bone? Hillson (1986, p. 108) wrote that "there are other departures from pure hydroxyapatite in calcified tissues." Hillson is referring to water-containing minerals percolating through the minute pores of buried skeletal material. This would also apply to buried fecal or stomach content material. He continues by stating that "common substitutions are sodium or strontium in the place of calcium, orthophosphate, carbonate or bicarbonate instead of phosphate, chlorine or carbonate in the place of hydroxyl" (Hillson, 1986, p. 108).

Furthermore, additional ions and molecules may be adsorbed onto the surface of apatite crystals. The solubility of apatites seems to depend on the pH of the environment. So we understand that excessive acidity (low pH) would dissolve the tooth and bone, while alkalinity would preserve it.

Therefore, how is the phosphate portion of apatite leached in an alkaline environment unless it was first acidic? This burial is probably best described in two phases. Phase I was in a very acidic reptilian stomach, but phase I was brought to an abrupt halt; otherwise the mandible would have been completely digested as seen in the digestion of modern crocodiles (Andrews and Fernando-Jalvo, 1998).

Then phase II began, and the mass alkalinized due to some ancient environmental conditions, including the influx of mineralized water percolating through the stomach contents. Also, there had to have been some selective leaching of the phosphate out of the hydroxyapaptite crystals of the mandible and tooth.

Several scientists have reported the ability of different bacterial species to solubilize inorganic phosphate compounds, including hydroxyapatite and rock phosphate. Strains of *Pseudomonas*, *Bacillus* and *Rhizobium*, demonstrate this ability (Rodriguez and Fraga, 1999). Phosphate solubilizing microorganisms are largely fungi and bacteria, which can exist on phosphorous-containing compounds (Goud et. al., 2008).

It seems reasonable to conclude, then, that postmortem bacterial overgrowth solubilized the phosphate in the hydroxyapatite and had little to no effect on the calcium. The other possibility is the substitution of CO_3^{2-} for PO_4^{3-}. A study on red deer, in France at the Lazaret cave, suggests that carbonate increases during fossilization and substitutes for PO_4^{3-} at one site and for OH^- at another site (Michel et al., 1995). However the authors also state that these were only "slight structural and chemical changes considering their geological age" (Michel et. al., 1995, p. 145).

Mammalian Origin

The mandible has been determined to be of mammalian origin. The presence of Hunter–Schreger Bands (HSB, alternating light and dark lines in enamel) is sufficiently diagnostic in distinguishing mammalian from reptilian teeth. Furthermore, reptilian enamel is not comparable at all to mammalian enamel. All reptilian taxa, with the exception of the agamid lizard *Uromastyx*, are without prisms in their enamel (Sander 1999). Mammalian enamel contains prisms.

Two experts (M. Ross and D. Moeller, personal communication, July, 22, 2010) with whom we consulted, have suggested that this mammalian jaw be assigned to the group called multituberculates, an extinct group of early mammals that have been found in the same (evolutionary-assumed) time frame as the *T. rex*. However, this conclusion has a problem.

None of the multituberculates have bladelike lower molars (Anonymous, n.d.). They do possess bladelike premolars with serrations but no premolar is preserved in this mandible. Therefore, this rules out a multituberculate origin due to this preserved specimen containing a bladelike lower molar.

Carlson and Krause (1985, p.1) studied the enamel microstructure of multituberculate mammals, and stated:

> Our review of Late Cretaceous and early Tertiary multituberculates reveals remarkable consistency in ultrastructure type at the subordinal level. All of the 13 recognized ptilodontoid genera were examined; all but two (*Cimolodon* and *Boffius*) possess small circular prisms that are numerous and closely-spaced. Twelve of 20 recognized taeniolabidoid genera were examined; all but three … possess large arcade-shaped prisms that are few in number and widely spaced … All but one (*Viridomys*) of the seven genera currently classified as Suborder incertae sedis possess large, arcade-shaped prisms.

Figure 19 is the first of the SEM images showing the radial fracture in the mid-crevice section of the molar, exposing the inner surface of the distal cusp. Note the dark, undulating bands of fractured enamel prisms running from lower left to upper right—these are the HSB mentioned earlier. These wavy prisms produce greater resistance to variable directions of force on the biting surface.

The uppermost edge of the cusp is the occlusal surface. Here, there is usually only a thin layer of zone-free enamel in the crown surface (Hillson, 1986). And the occlusal surface in Figure 19

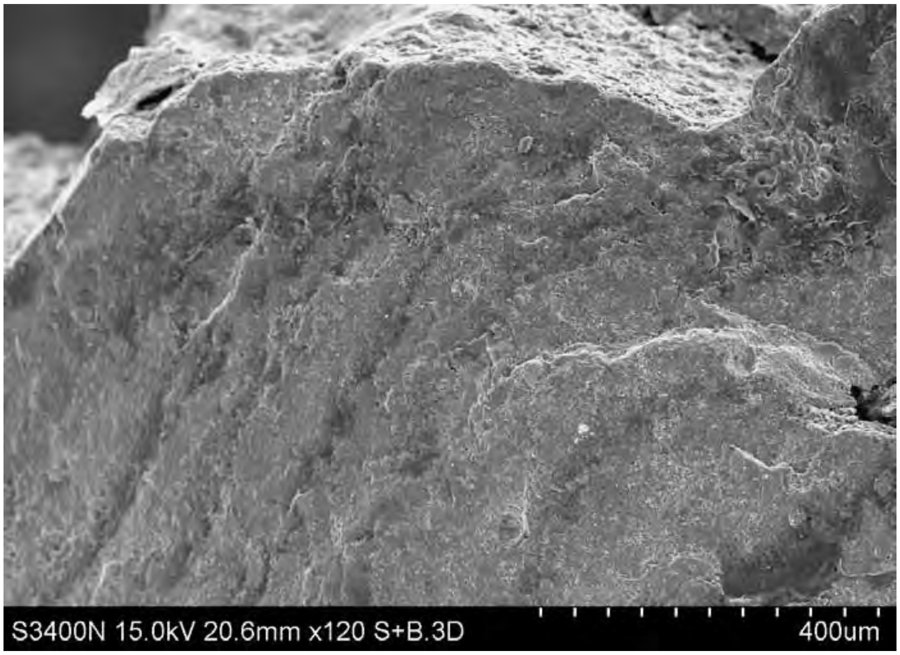

Figure 19. SEM image of radial fracture in mid-crevice of molar (magnification = 120x).

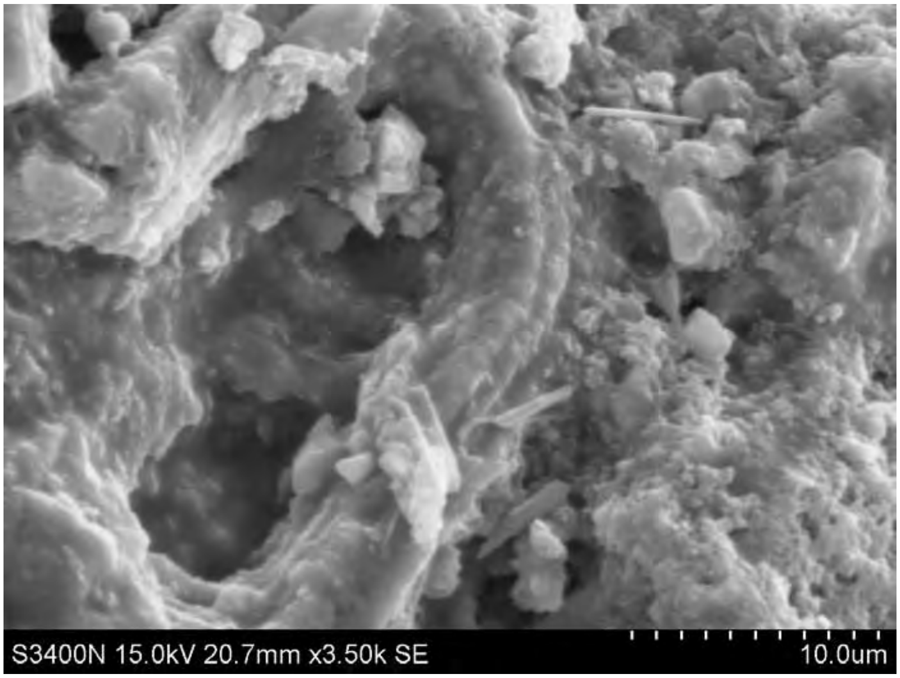

Figure 20. SEM image of curved enamel prisms (rods) arcade in shape and bound together. Broken ends are visible in upper left-hand corner (magnification = 3,500x).

appears to be mostly zone-free enamel.

In Figure 20 are the bundles of enamel crystallites called prisms or rods, seen in this oblong-shaped structure bound together by interprismatic enamel. In the upper left corner, two rods have been separated due to the enamel fracture, and two rods, the most superior and most inferior, are still connected to the bundle.

These broken ends of the rods are not circular but are arcade-shaped. Notice also the lumps or discontinuities in the rods. It is important to observe that the length of these bumps on the rods are about 1–2 μm in length.

In Figure 21, the wavy and terminally curved enamel rods are connected by sheaths and are twisted (decussating) in their form with individual discontinuities (lumps). This represents cyclical variation in the enamel matrix secretion rate (Hillson, 1996). The striations between the lumps have been called slower secretion or pauses in secretion. Based on human and animal observations, Hillson (1996) explains that these cross striations represent a 24-hourly or circadian rhythm.

In our research, if these small 1–2 micron secretions (lumps) are truly the amount produced daily, then each one of these represents a much slower rate of growth than what we see today.

This is an intriguing discovery because the modern average of 4.3 to 4.9 microns per day that was set forth by Bromage (1991) in *Macaca nemestrina* and mean rates per day of 4.70 ±0.73 to 5.12±0.60 microns per day for two species of *Sivapithecus* (Mahoney et al., 2007) are larger and imply faster enamel development.

Figure 22 shows that the decussating enamel rods are broken in places. Observe the horseshoe, or arcade, shape of the end of the partial rod in the uppermost left-hand side.

Figure 23 is a close-up of Figure 22. The interprismatic connections between the enamel rods that have a left-right direction in Figure 23 are called bridges of enamel. They are different than the interrow sheets of enamel seen in Figure 24. The interrow sheets of interprismatic enamel that connect the

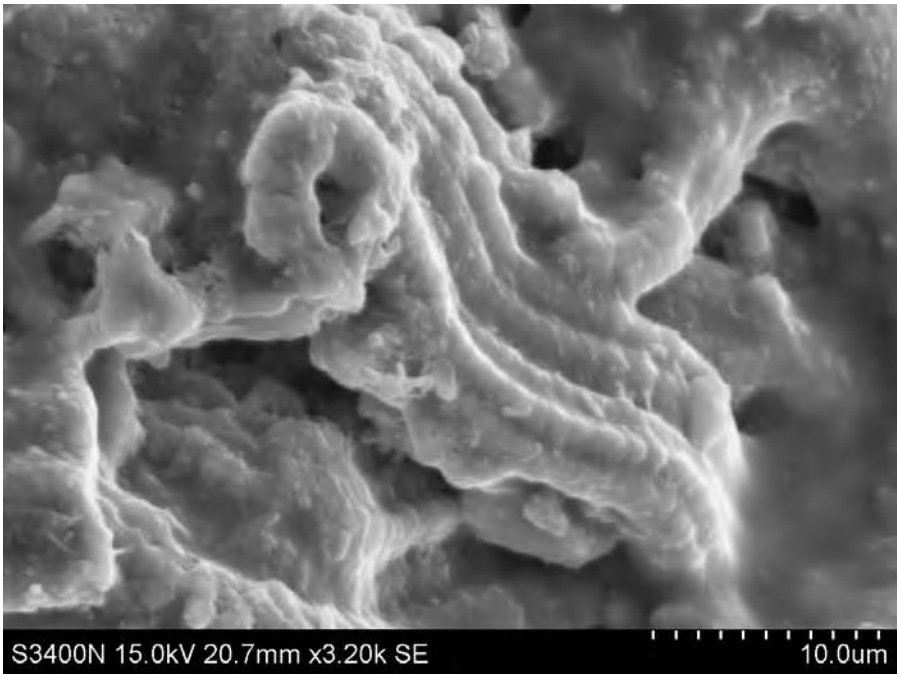

Figure 21. Twisted enamel prisms (rods) forming a woven, crystalline structure known as prism decussation. Note the bumps on the prisms. These are the "daily secretions" and much smaller than the modern-day 24-hour circadian secretions.

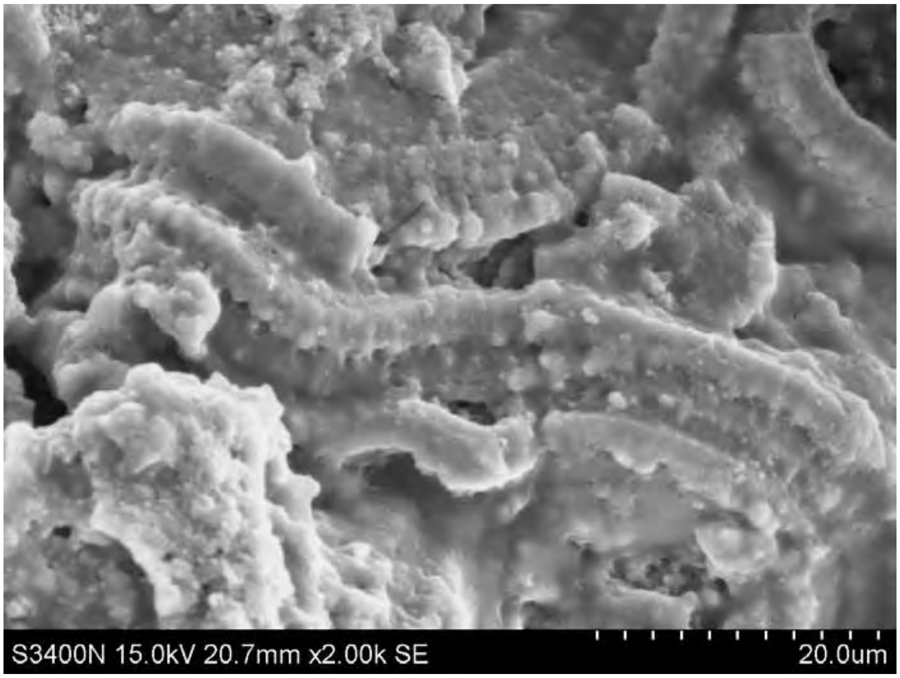

Figure 22. Twisted enamel rods with bridges of enamel.

vertical straight rows of prisms or rods are more indicative of Pattern 2; the enamel bridges in Figure 23 suggest a Pattern 3 structure (Boyde, 1965).

Summary

Neither the mass matrix nor the tooth or bone has any preserved phosphate that could be detected. However, the femur, which is only 45 meters away, does have recognizable amounts. It is reasonable to believe that if this small mammal bone was independently fossilized outside of its present matrix, near the other *T.rex* bones, which contain phosphate, that the mammalian bone would contain phosphate too. The fact that no phosphate is found in the mammalian remains suggests that this matrix is not a fecal mass but was fossilized internally and was stomach contents. This being partially digested stomach contents, rather than discharge excrement, was the fortunate, highly rare variable that allowed the mammalian remains to be discovered.

It can be assumed that since the mandibular bone itself was not digested or dissolved, as happens within a few hours inside a crocodile, then the dinosaur died very quickly after its last meal. Further, its stomach's extremely acidic environment was diluted quite rapidly with a watery mud and sand mix. A flood of this sort, which could envelop a creature like a *T.rex* so completely, points to a watery cataclysm, which was most likely Noah's Flood (Genesis 7–8).

The mandible belonged to a small mammal, based on its enamel rods seen in the electron microscope images. The enamel rods decussate (twist) in many locations and are straight in others. There are enamel bridges in some and interrow interprismatic enamel in others. With these findings it is possible to assign, with some reservation, the mammal enamel microstructure to Pattern 2 in some areas and Pattern 3 in others (Boyde, 1965).

The electron microscope studies revealed a slower-than-modern-day development of the circadian (daily) mammalian dental enamel prisms. This may suggest a prolonged development in this mammal, which may impact lifespan.

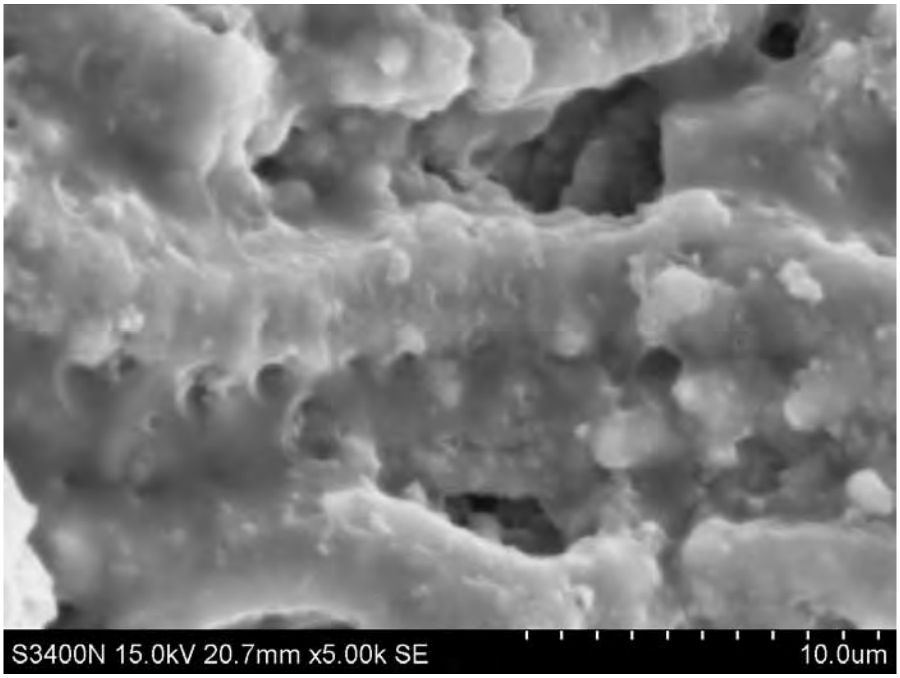

Figure 23. Bridges of interprismatic enamel between the rods. This is a close-up of Figure 22.

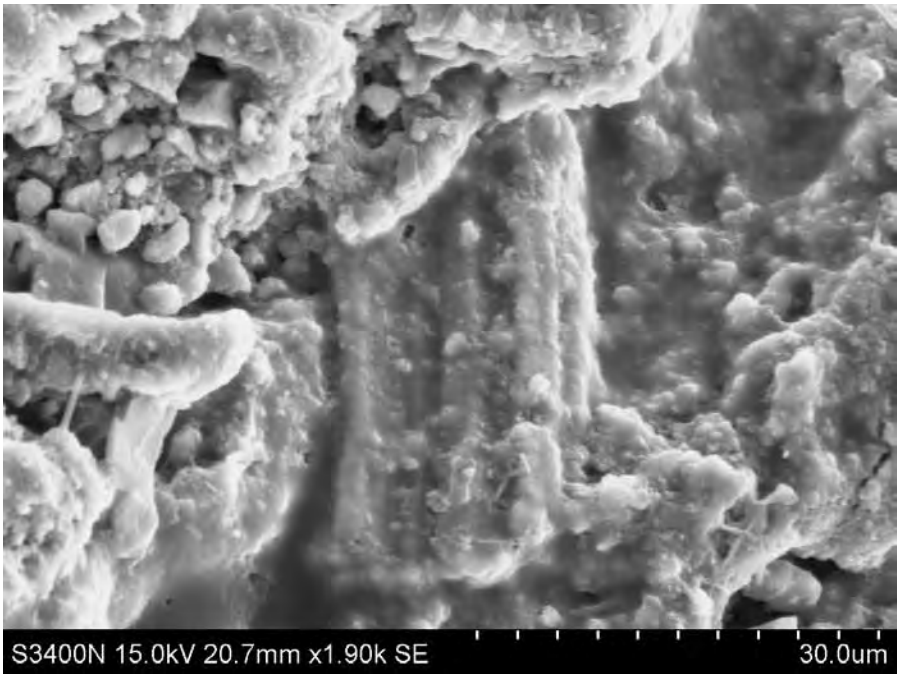

Figure 24. Straight bundles of rods.

Currently, this find is most accurately attributed to Mammalia, Incertae sedis.

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