Quantitative Analysis of 4468 Uroliths Retrieved from Farm Animals, Exotic Species, and Wildlife Submitted to the Minnesota Urolith Center: 1981 to 2007

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KEYWORDS

• Exotic • Zoo • Wildlife • Uroliths • Calculi
• Quantitative analysis

Knowledge of the mineral composition of uroliths in various species of animals can often help veterinarians predict the mineral composition of stones in vivo. This information is important because dissolution of existing uroliths, or minimizing further growth of uroliths in situ, is dependent on knowledge of the mineral composition of uroliths.

With this objective in mind, this report summarizes the results of quantitative mineral analysis of uroliths retrieved from 4468 farm animals, wildlife, and so-called ''exotic'' species of animals and sent to the Minnesota Urolith Center by various individuals living primarily in North America, Eastern Europe, Australia, New Zealand, and Asia. We have reported the methods we used to identify and classify various minerals found in these uroliths.[1] The information provided in this report summarizes the most extensive database about uroliths from animals other than domesticated dogs and domesticated cats that we could identify in the literature.

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We have also included selected reports of uroliths in the English literature related to specific stones that we have evaluated (**Appendix 1**). We did not include reports of uroliths whose composition was not described, or reports of uroliths evaluated by insensitive qualitative techniques.

We encourage our colleagues to continue to send us uroliths retrieved from farm animals, exotic species, and wildlife for evaluation by quantitative techniques. Because of the strong support of an educational grant from Hill's Pet Nutrition, we are able to provide this service without a monetary fee. However, to gain insights into the epidemiology of urolithiasis, we ask that each submission be accompanied by a one page urolith analysis request form. This form can be found at our Web site: www.cvm.umn.edu. Click on the link to department and centers to find Minnesota Urolith Center, and follow the menu to the request form. The details are available under the icon labeled "How to submit samples." For colleagues residing outside the borders of the United States, packaging instructions for noninfectious clinical samples may be found at: http://www.usps.com/, US Postal Service Packaging Instruction 6C. Alternatively, contact your preferred shipper for instructions about complying with International Air Transportion Association Regulation 3.6.2.2.3.6. We comply with all federal and state regulations regarding handling and shipment of samples that are a potential source of diseases that are communicable to animals and humans. Information on acceptable species for USA importation and documentation necessary for the United States Department of Agriculture (USDA) customs inspection can be found under guidelines 1102, 1103, and 1104 at: www.aphis.usda.gov/.

Appendix 1
Quantitative analysis of 4468 uroliths retrieved from farm animals, exotic species, and wildlife sent to the Minnesota Urolith Center: 1981–2007

Animals	No. (%)
Carnivore	
Bobcat uroliths (n=2)	
Struvite	2 (100)
Bush dog uroliths (n=2)	
Struvite	1 (50)
Purines	1 (50)
Cape hunting dog uroliths (n=1)	
Calcium phosphate	1 (100)
Caracal (Persian lynx) uroliths (n=3)	
Calcium oxalate	2 (66.7)
Miscellaneous	(33.3)
Cheetah uroliths[2] (n=2)	
Calcium phosphate	1 (50)
Purines	1 (50)
Cougar uroliths (n=1)	
Calcium phosphate	1 (100)
Cusimanse (Dark mongoose) uroliths (n=3)	
Calcium oxalate	2 (66.7)
Compound	1 (33.3)

Ferret uroliths[a,3,4] (n=409)	
Struvite	273 (66.8)
Cystine	61 (14.9)
Calcium oxalate	43 (10.5)
Purines	8 (2.0)
Matrix	6 (1.5)
Compound	4 (1.0)
Mixed	4 (1.0)
Other	4 (1.0)
Calcium phosphate	3 (0.7)
Silica	1 (0.2)
Calcium carbonate	1 (0.2)
Magnesium hydrogen phosphate	1 (0.2)
Fox uroliths[b] (n=27)	
Struvite	21 (77.8)
Cystine	3 (11.1)
Calcium oxalate	1 (3.7)
Calcium phosphate	1 (3.7)
Compound	1 (3.7)
Leopard uroliths[c] (n=14)	
Struvite	5 (35.7)
Calcium oxalate	1 (7.1)
Calcium phosphate	3 (21.4)
Mixed	3 (21.4)
Compound	1 (7.1)
Miscellaneous	1 (7.1)
Lion uroliths[5,6] (n=6)	
Calcium oxalate	4 (66.66)
Struvite	1 (16.66)
Mixed	1 (16.66)
Lynx uroliths[7] (n=2)	
Calcium oxalate	1 (50)
Silica	1 (50)
Mink uroliths[d] (n=22)	
Struvite	22 (100)
Mongoose uroliths (n=4)	
Calcium phosphate	2 (50)
Mixed	2 (50)
Otter uroliths[e8–11] (n=108)	
Calcium oxalate	60 (55.6)
Compound	29 (26.9)
Purines	9 (8.33)
Mixed	6 (5.6)
Calcium carbonate	2 (1.9)
Struvite	2 (1.9)

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Appendix 1
(continued)

Animals	No. (%)
Raccoon uroliths[12] (n=21)	
Purines	17 (80.9)
Compound	2 (9.5)
Calcium oxalate	1 (4.8)
Mixed	1 (4.8)
Tiger uroliths[f] (n=3)	
Struvite	2 (66.7)
Miscellaneous	1 (33.3)
Wolf uroliths[g13] (n=39)	
Cystine	30 (76.9)
Struvite	4 (10.3)
Mixed	2 (5.1)
Calcium oxalate	1 (2.6)
Compound	1 (2.6)
Other	1 (2.6)
Ruminant	
Bison uroliths (n=2)	
Calcium oxalate	2 (100)
Bongo (large, forest-dwelling antelope) uroliths (n=2)	
Calcium oxalate	2 (100)
Bovine (domestic) uroliths[14–24] (n=217)	
Struvite	73 (33.6)
Silica	43 (19.8)
Magnesium calcium phosphate	8 (3.7)
Magnesium calcium phosphate carbonate	28 (12.9)
Compound	17 (7.8)
Calcium phosphate	17 (7.8)
Mixed	14 (6.5)
Calcium carbonate	8 (3.7)
Calcium oxalate	4 (1.8)
Purines	2 (0.9)
Matrix	2 (0.9)
Other	1 (0.5)
Camel uroliths[25] (n=5)	
Silica	4 (80)
Purines	1 (20)
Caprine (domestic) uroliths[26–32] (n=526)	
Calcium carbonate	224 (42.6)
Magnesium calcium phosphate carbonate	101 (19.2)
Silica	76 (14.5)
Compound	34 (6.5)
Magnesium calcium phosphate	24 (4.6)
Struvite	19 (3.6)

Mixed	21 (4)
Calcium phosphate	16 (3)
Calcium oxalate	4 (0.8)
Other	4 (0.8)
Matrix	2 (0.4)
Purines	1 (0.1)
Caribou (reindeer-like animal) uroliths (n=3)	
Calcium oxalate	3 (100)
Deer uroliths[33] (n=12)	
Struvite	3 (25)
Magnesium calcium phosphate	2 (16.7)
Magnesium calcium phosphate carbonate	2 (16.7)
Mixed	2 (16.7)
Calcium phosphate	1 (8.3)
Calcium carbonate	1 (8.3)
Miscelleneous	1 (8.3)
Duiker (small antelope) uroliths (n=4)	
Struvite	1 (25)
Purines	1 (25)
Magnesium calcium phosphate carbonate	1 (25)
Mixed	1 (25)
Gazelle (African antelope) uroliths (n=1)	
Purines	1 (100)
Gemsbok (large African antelope) uroliths (n=1)	
Calcium phosphate	1 (100)
Giraffe uroliths[34] (n=12)	
Magnesium calcium phosphate carbonate	4 (33.3)
Magnesium calcium phosphate	3 (25)
Mixed	3 (25)
Struvite	1 (8.3)
Other	1 (8.3)
Greater Kudu (Woodland antelope) uroliths (n=5)	
Other	2 (40)
Magnesium calcium phosphate	1 (20)
Calcium phosphate	1 (20)
Miscellaneous	1 (20)
Llama uroliths[35,36] (n=24)	
Silica	18 (75)
Struvite	2 (8.3)
Calcium phosphate	1 (4.2)
Purines	1 (4.2)
Magnesium calcium phosphate carbonate	1 (4.2)
Calcium carbonate	1 (4.2)
Moose uroliths (n=2)	
Calcium carbonate	2 (100)

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Appendix 1
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Animals	No. (%)
Mouflon (wild mountain sheep) uroliths (n=5)	
Calcium phosphate	2 (40)
Struvite	1 (20)
Magnesium calcium phosphate	1 (20)
Mixed	1 (20)
Muntjac (type of deer) uroliths (n=1)	
Calcium phosphate	1 (100)
Ovine (domestic) uroliths[21,22,29,31,37–39] (n=111)	
Calcium carbonate	33 (29.7)
Magnesium calcium phosphate carbonate	22 (19.8)
Struvite	16 (14.4)
Calcium phosphate	14 (12.6)
Silica	12 (10.8)
Mixed	7 (6.3)
Matrix	3 (2.7)
Compound	2 (1.8)
Calcium oxalate	1 (0.9)
Other	1 (0.9)
Tahr (goat-like animal) uroliths (n=4)	
Purines	3 (75)
Calcium phosphate	1 (25)
Wildebeest uroliths (n=4)	
Calcium carbonate	3 (75)
Purines	1 (25)
Equine	
Equine (domestic) uroliths[40–49] (n=256)	
Calcium carbonate	243 (94.9)
Compound	4 (1.6)
Struvite	3 (1.2)
Calcium oxalate monohydrate	2 (0.8)
Magnesium calcium phosphate carbonate	1 (0.4)
Mixed	1 (0.4)
Matrix	1 (0.4)
Other	1 (0.4)
Porcine	
Peccary (pig-like hoofed mammal) uroliths (n=1)	
Compound	1 (100)
Porcine (domestic) uroliths[50–55] (n=95)	
Calcium phosphate	33 (34.7)
Struvite	18 (18.9)
Mixed	13 (13.7)
Magnesium calcium phosphate carbonate	9 (9.5)
Compound	9 (9.5)

Magnesium calcium phosphate	3 (3.2)
Calcium carbonate	3 (3.2)
Silica	3 (3.2)
Calcium oxalate	2 (2.1)
Purines	1 (1.1)
Other	1 (1.1)
Rodent	
Rabbit (domestic) uroliths[56–61] (n=1011)	
Calcium carbonate	702 (69.4)
Compound	232 (23)
Mixed	33 (3.3)
Calcium phosphate	14 (1.4)
Magnesium calcium phosphate carbonate	11 (1.1)
Calcium oxalate	9 (0.9)
Silica	4 (0.4)
Magnesium calcium phosphate	3 (0.3)
Struvite	2 (0.2)
Matrix	1 (<0.01)
Capybara (large South American rodent) uroliths (n=2)	
Calcium carbonate	2 (100)
Chinchilla uroliths[62,63] (n=73)	
Calcium carbonate	64 (87.7)
Miscellaneous	5 (6.8)
Compound	4 (5.5)
Groundhog uroliths (n=1)	
Struvite	1 (100)
Guinea pig uroliths[64–68] (n=948)	
Calcium carbonate	878 (92.6)
Compound	27 (2.8)
Mixed	15 (1.6)
Calcium phosphate	10 (1.1)
Matrix	9 (1.0)
Calcium oxalate	4 (0.4)
Magnesium calcium phosphate	2 (0.2)
Other	2 (0.2)
Struvite	1 (0.1)
Hamster uroliths (n=14)	
Calcium phosphate	4 (28.6)
Compound	4 (28.6)
Calcium oxalate	3 (21.4)
Struvite	2 (14.3)
Mixed	1 (7.1)
Mice uroliths[69,70] (n=39)	
Struvite	37 (94.9)
Matrix	2 (5.1)

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Appendix 1
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Animals	No. (%)
Porcupine uroliths (n=3)	
Calcium phosphate	1 (33 3)
Compound	1 (33.3)
Matrix	1 (33.3)
Rat uroliths[71–77] (n=51)	
Struvite	41 (80.4)
Calcium phosphate	3 (5.9)
Calcium carbonate	2 (3.9)
Other	2 (3.9)
Mixed	1 (2)
Magnesium hydrogen phosphate	1 (2)
Magnesium calcium phosphate carbonate	1 (2)
Squirrel uroliths (n=2)	
Purine	1 (50)
Compound	1 (50)
Marsupial	
Kangaroo uroliths[78,79] (n=15)	
Calcium carbonate	8 (71.9)
Calcium oxalate	3 (20)
Compound	2 (13.3)
Silica	1 (6.7)
Purines	1 (6.7)
Opossum uroliths (n=8)	
Struvite	7 (87.5)
Mixed	1 (12.5)
Wallaby uroliths (n=7)	
Calcium carbonate	6 (85.7)
Compound	1 (14.3)
Wombat uroliths[h] (n=1)	
Calcium oxalate	1 (100)
Cetacea	
Dolphin uroliths[80] (n=13)	
Purines	11 (84.6)
Calcium phosphate carbonate	1 (7.7)
Struvite	1 (7.7)
Harbor porpoise uroliths (n=1)	
Struvite	1 (100)
Whale uroliths[81] (n=2)	
Calcium phosphate	1 (50)
Purines	1 (50)
Fish	
Angel fish uroliths (n=2)	
Calcium phosphate	2 (100)

Lion fish uroliths[i] (n=3)	
Calcium phosphate carbonate	3 (100)
Northern kingfish uroliths[j] (n=1)	
Calcium hydrogen phosphate dehydrate	1 (100)
Porkfish uroliths[k] (n=1)	
Calcium phosphate	1 (100)
Rainbow trout uroliths (n=1)	
Calcium phosphate carbonate	1 (100)
Sand tiger shark uroliths (n=1)	
Calcium phosphate carbonate	1 (100)
Primate	
Ape and monkey uroliths[82–84] (n=42)	
Calcium carbonate	26 (62)
Calcium oxalate	7 (16.6)
Struvite	2 (4.7)
Cystine	2 (4.7)
Calcium phosphate	4 (9.5)
Matrix	1 (2.3)
Reptile	
Gecko uroliths (n=2)	
Other	1 (50)
Purines	1 (50)
Iguana uroliths[85] (n=140)	
Purines	136 (97.1)
Mixed	3 (2.1)
Compound	1 (0.7)
Lizard uroliths (n=26)	
Purines	24 (92.3)
Calcium carbonate	1 (3.8)
Compound	1 (3.8)
Tortoise uroliths (n=66)	
Purines	62 (93.9)
Calcium carbonate	2 (3.0)
Mixed	2 (3.0)
Turtle uroliths[86] (n=12)	
Purines	7 (58.3)
Calcium phosphate	2 (16.7)
Compound	2 (16.7)
Mixed	1 (8.3)
Other	
Elephant uroliths (n=3)	
Calcium carbonate	2 (66.6)
Calcium phosphate	1 (33.3)
Harbor seal uroliths[l87] (n=3)	
Purines	3 (100)

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Appendix 1
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Animals	No. (%)
Hippopotamus uroliths (n=2)	
Calcium oxalate	2 (100)
Shrew uroliths (n=2)	
Struvite	1 (50)
Calcium oxalate	1 (50)
Sloth uroliths (n=7)	
Struvite	3 (42.9)
Compound	2 (28.6)
Magnesium phosphate	1 (14.3)
Mixed	1 (14.3)
Tapir uroliths[m] (n=1)	
Calcium carbonate	1 (100)
Total	***4468***

[a] Studies are in progress to determine if naturally occurring sterile-struvite uroliths can be safely dissolved by formulating an urine-acidfying magnesium-restricted diet.
[b] Information regarding the status of urinary tract infections is unknown. Therefore, we cannot determine if the struvite uroliths were induced by urease producing microbes or if the struvite formed in sterile urine.
[c] Please see comments for fox uroliths.
[d] Struvite uroliths in mink are usually the result of urinary tract infections with urease-producing microbes.
[e] Calcium oxalate uroliths are very common in captive Asian small clawed otters. Uroliths composed of salts of uric acid have been observed in American river otters and Eurasian otters.
[f] Please see comments for fox uroliths.
[g] We have observed cystine uroliths in several grey wolves living in northern Minnesota.
[h] Australian marsupials are short-legged muscular quadrupeds, approximately 39 inches in length with a very short tail.
[i] Otherwise known as turkey fish or dragon fish. Lionfish are venomous and are noted for their extremely long and separated spines. They usually have a striped appearance: red, brown, orange, yellow, black, maroon, or white.
[j] Kingfish is the common name of a number of different species of fish, including the king mackerel, the cero, the northern kingfish (also called northern king whiting), and the southern kingfish (southern king whiting). The northern kingfish is a bottom-dwelling fish that feeds on shrimp, small fish, and crabs. It grows to a length of 18 inches, and is found in coastal waters from Massachusetts to Yucatán.
[k] Also known as grunts. A member of the grunt family, the porkfish can produce a peculiar grunting sound by rubbing together the teeth in its throat. They have a "smiling" expression when their mouths are closed. When open, their mouths show a bright red lining, which they often display to each other in territorial contests. Grunts are a group of small to midsize bass-like fishes that have deep, compressed, oval-shaped bodies.
[l] Elephant seals and sea lions (or sea elephants) are a true seal of the genus Mirounga. They are the largest of the fin-footed mammals, or pinnipeds, exceeding the walrus in size. The eared seals (or otariids) are marine mammals in the family Otariidae, one of three groupings of Pinnipeds. They comprise 16 species in seven genera commonly known either as sea lions or fur seals, distinct from true seals (phocids) and walruses (odobenids).[88]
[m] Tapirs (pronounced "taper" or "ta-pier") are large browsing mammals, roughly pig-like in shape, with short prehensile snouts.

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