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RODENT-GNAWED CARBONATE ROCKS FROM INDIANA

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ABSTRACT. Two carbonate-rock specimens from Jasper County and Monroe County, Indiana, are marked superficially by numerous grooves left by lower incisors of modern rodents. The Jasper County specimen is a calcitic dolomite, with incisor marks most closely matching size ranges for *Sciurus* (?)*carolinensis* (gray squirrel), *Tamias striatus* (eastern chipmunk) and mouse-sized species. The Monroe County specimen is dolomitic limestone showing marks in the size range of *Sciurus niger* (fox squirrel), *Marmota monax* (woodchuck), mouse-sized species, and possibly the lagomorph *Sylvilagus floridanus* (eastern cottontail). Both rocks contain an abundance of calcium, magnesium and clay minerals which may have been a source of nutrients for the rodents, but also contain significant amounts (*ca.* 20%) of SiO_2 (quartz), which may act as a fine abrasive for wearing down ever-growing incisors. Weathering has softened the surface of both rock samples, thus facilitating the gnawing activity and perhaps explaining why several different species selected these particular rocks upon which to gnaw. It is also possible that once rodents had gnawed and deposited their scent on the rocks, other rodents would be attracted to inspect and gnaw the rocks in turn. However, there is as yet no record of such behavior among Indiana rodents.

Keywords: Gnaw marks, rodents, Ramp Creek, Rockford Limestone.

It is well-known that members of the Order Rodentia, whose name translates to "the gnawers," will chew on bones in the wild, and that "pest" species, such as *Mus musculus* (house mouse), chew through wood, plastic and many other materials they encounter. By comparison, the gnawing of rocks by rodents is rarely observed. Cuffey & Hattin (1965) reported gnawing of chalk by *Sylvilagus audobonii* (desert cottontail); and Gow (1992) observed African porcupines, presumably *Hystrix,* gnawing a siltstone ledge. Apart from these references, few or no studies have focused on rock-gnawing and its importance. Samples of carbonate rock from two Indiana counties situated about 200 km apart show significant modification of rock surfaces by rodent gnawing. The marks were probably produced within a few years' time because, in the Indiana climate, limestone erodes readily with exposure to the elements; and such marks are likely to be dulled or obliterated within a relatively short time.

Gnaw marks appear as paired, in some places divergent, grooves of wide-ranging size. The marks show the scoop-like, U-shaped cross-section typical of lower incisors rather than the flat-edged cross-section left by upper incisors (Burns et al. 1989). Imprints of upper teeth, left when the rodent braces its upper incisors against the gnawed surface (Burns et al. 1989), are not preserved. In rodents, the mandibular symphysis between the lower incisors spreads as the jaw muscles contract. This causes the teeth to diverge and function as tweezers, and enables the rodent to scrape around corners, so that the lower incisors are more maneuverable than the uppers and are the pair most often used to gnaw. Rodents which burrow through hard-packed soils use lower incisors rather than uppers (Burns et al. 1989; Zuri et al. 1999), so lower incisors are more likely to be used on hard rock. The Indiana samples suggest gnawing activity by more than one rodent species, as the tooth marks vary greatly in size. This study is aimed at identifying tooth marks to rodent taxa, and investigating whether rodents gnaw for nutritional purposes, for wearing down their teeth, or both, and whether gnawing is a response to local environmental conditions or implies more widespread behavior and physiological needs.

METHODS

To identify rodent taxa which might have produced the tooth marks on the Jasper and Monroe County carbonate-rock samples, widths of various-sized single and paired grooves were measured on each sample and compared with lower incisor widths from several species of rodents and lagomorphs known to be common in these counties. Rare taxa, or those with incisor widths well outside the range suggested by the tooth marks on the rocks, were not included. Mandibles from Indiana species were placed directly against the tooth marks on the rocks to find an approximate size match before they were measured. Skeletal specimens used in this study are part of the mammal collections in the Zooarchaeology Laboratory at Indiana University Bloomington, with the exception of one *Marmota monax* skull from the Division of Mammals in the University of Kansas Natural History Museum. Incisors were measured in place in alveoli, and each tooth or pair of teeth was measured as close to the occlusal (gnawing) edge as possible. All measurements were made to the nearest 0.1 mm with dial calipers.

Mandible specimens used were as follows; they are in the Indiana University Bloomington Zooarchaeology Laboratory unless otherwise specified. "IU" refers to Indiana University Bloomington; "KU" refers to the Division of Mammals, University of Kansas Natural History Museum. The specimens were: *Marmota monax:* IU 901152, 9310936, 9510208, 9610169, 9710153, A3, A51, AA32, BB16, M1, M6, K23, K76, S83, S94, T22; KU RMT4126. *Sciurus niger:* IU 84152, 84154, 84156, 84159, 841119, 841146, 8410067, 921225, 9110587, 9310582, 9310595, 9810182, HH76; immature specimens IU 369, 891382, 891383, 9610128, EE7. *Sciurus carolinensis:* IU 84122, 84124, 9610225, 9610226, D72, J16; immature specimens IU 9710476, M26. *Tamias striatus:* IU 84141, 9710371, EE61, W98, also one unnumbered specimen; immature specimen IU DD20. *Rattus norvegicus:* IU AA54; *Peromyscus maniculatus:* IU S91; *Peromyscus leucopus:* IU 9810007; *Zapus hudsonicus:* IU FF79.

RESULTS

Description of rock samples.—Specimens of rodent-gnawed rock which are the principal basis for this study consist of impure, fine-grained carbonate rocks, including one sample from the lower Mississippian Rockford Limestone and one from the middle Mississippian Ramp Creek Formation. The Rockford specimen is a much-weathered, mostly dark yellowish-orange (10 YR 6/6 on Geological Society of America Rock-color Chart) calcitic dolostone, as determined from acid-reaction tests (Low 1951), thin sections, and x-ray diffraction analysis. This rock has a primarily microcrystalline texture, with grayish-colored patches of micrite which do not react to alizarin red S solution. A small part of the rock comprises coarsely crystalline calcite containing abundant silt and very fine sand-sized dolorhombs. Accessory components include silt-sized quartz (SiO_2) grains, which are locally abundant, and silicified skeletal remains derived primarily from crinoids that are scattered irregularly throughout. A small sample of this specimen was digested in hydrochloric acid (HCl), producing an insoluble residue amounting to 21.17% of the rock. X-ray diffraction analysis of the residue shows quartz as the dominant residue component, with scarcely more than trace quantities of magnesium calcite $(Ca, Mg)CO_3$ and the clay mineral illite $(KAl_2(OH_2).[AlSi_3(O,OH)_{10}])$. This specimen, which is almost completely covered with tooth marks (Fig. 1), was collected by N. Gary Lane from a ditch near the center of section 21, T 27N, R 7W, Jasper County, Indiana. The locality and rock section are described by Gutschick & Treckman (1957).

The Ramp Creek sample is a moderate yellowish-brown (10 YR 5/4) dolomitic limestone as determined by the same testing methods used on the Rockford sample. This rock has a very fine grained microsparry matrix, in which are scattered very fine sand- and silt-sized rhombs of dolomite ($MgCO_3$), mostly silt-sized angular grains of quartz, and sand- to very fine gravel-sized skeletal grains derived from crinoids. The skeletal grains retain their calcitic composition, as determined from optical and staining techniques. As with the Rockford sample, a small portion of this sample was digested in hydrochloric acid, producing an insoluble residue representing 20.59% of the original rock. X-ray diffraction analysis of the residue shows quartz as the overwhelmingly predominant residue component, with little more than trace quantities of magnesium

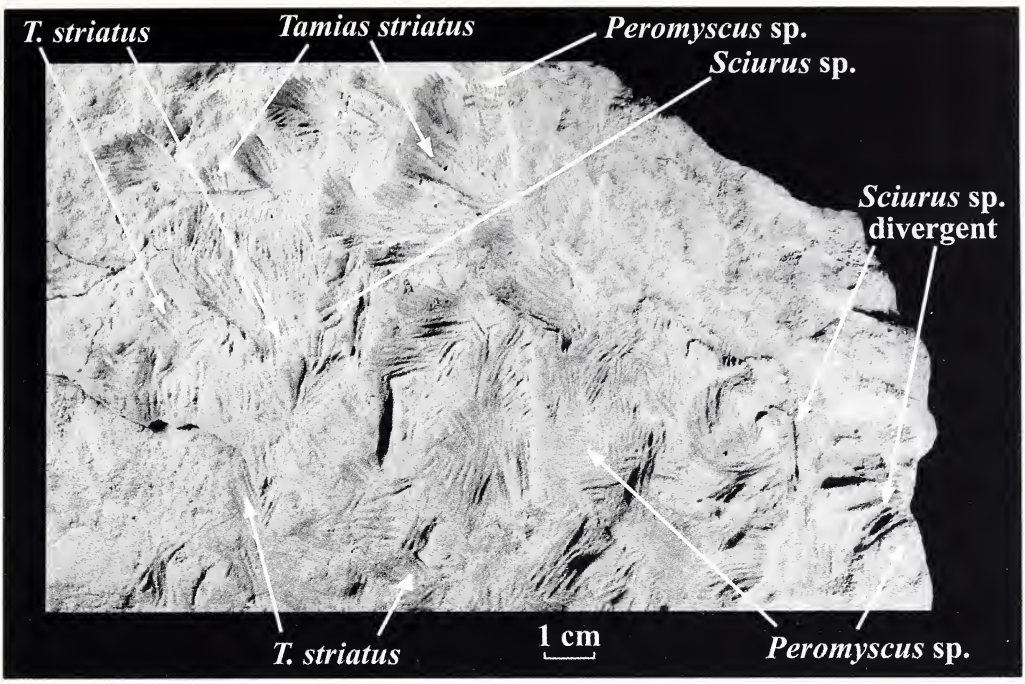

Figure 1.—Rockford Limestone slab (lower Mississippian) from Jasper County, Indiana, showing numerous marks left by rodent lower incisors. Labels denote best-preserved sets of tooth marks, with approximate identification of rodent species.

calcite, illite, and kaolinite ($Al_2Si_2O_5(OH)_4$), in decreasing order of abundance. The Ramp Creek sample was collected in 1984 by former Indiana University student David Kring from a Monroe County locality believed to be at the east edge of Bloomington, Indiana, near the intersection of State Road 45 and Smith Road.

The Jasper County specimen measures 18.4 cm long and 29.8 cm wide, with roughly 50% of one surface marked by small, paired scrape- or groove-like tooth marks (Fig. 1). Gnawed portions and other relatively fresh surfaces are dark yellowish-orange, whereas more weathered portions appear yellowish-gray. The rock is soft, crumbling away slightly with handling so as to leave orange-colored dust on the fingers, and is easily scratched with a fingernail.

On the Jasper County specimen, paired gnaw-marks display a wide range of sizes. At least two sets of marks on this and the Monroe County sample diverge along their length, indicating the spreading of the mandibular symphysis (Fig. 1). Width of single tooth marks ranges from 0.2–1.1 mm, with a majority of marks being 0.9–1.0 mm across (Table 1). Width of paired marks ranges from 1.3–3.3 mm, with most pairs approximating 2.2 mm. Comparison with tooth measurements averaged for each Indiana rodent species suggests that 50% of measured marks correspond to lower incisor width of some species of *Sciurus*, possibly *S. carolinensis* (gray squirrel), incisor width, whereas about 25% match lower incisors of *Tamias striatus* (eastern chipmunk). There is one group of small tooth marks of *ca.* 0.5–0.9 mm single and 1.2–1.5 mm paired width (Fig. 1; Table 1) that appear to match tooth size of smaller Indiana rodents, such as *Peromyscus maniculatus* (deer mouse), *Peromyscis leucopus* (white-footed mouse), *Zapus hudsonicus* (meadow jumping mouse), *Microtus pennsylvanicus* (meadow vole), *Microtus orchrogaster* (prairie vole), *Microtus pinetorum* (woodland vole) and *Mus musculus* (house mouse).

The limestone specimen collected from Monroe County, Indiana is smaller than the Jasper County specimen, measuring 12.0 cm in length and 9.6 cm in width (Fig. 2). A rough sketch, presumably made by the collector, accompanies the specimen and indicates

Table 1.—Comparison of lower incisor widths measured from skeletal specimens with widths of tooth marks on Indiana carbonate rock specimens. The number of marks measured represents the best-preserved sets of marks on each rock, and does not necessarily reflect total number of marks of that size. Because tooth mark widths are approximate owing to imperfect clarity, identifications of rodent species are also estimates. All measurements are in mm.

Rock specimen	Rodent species	Range, single incisor width	Range, paired incisor width	Number of tooth marks	Range, single tooth mark	Range, paired tooth marks
Rockford Limestone (Jasper County)	*Marmota monax* (woodchuck)	2.1–4.1	4.9–9.7	5	3.4–3.8	5.5
	Sciurus niger (fox squirrel)	1.0–1.8	2.4–4.1	5	0.9–1.8	3.4–4.4
	Tamias striatus (eastern chipmunk and/or mouse-sized species)	0.4–1.1	1.3–2.6	2	0.6–0.9	1.7
Ramp Creek Formation (Monroe County)	*Sciurus carolinensis* (gray squirrel)	0.8–1.3	1.8–3.1	16	1.0–1.1	1.8–3.0
	Tamias striatus	0.4–1.1	1.3–2.6	8	0.8–0.9	1.8–2.4
	Peromyscus leucopus (white-footed mouse or *P. maniculatus* deer mouse)	0.7	1.2	4	0.7	1.2–1.5
	Zapus hudsonicus (meadow jumping mouse)	0.4	1.3	5	0.3–0.5	1.2–1.5

that the gnawed sample was collected on a steep slope beneath an overhanging ledge of bedrock. Tooth marks occur only on one side of the rock specimen and cover about 75% of that surface (Fig. 2).

This sample is comparable to the Jasper County specimen in texture, fossil content, and relative hardness, but the surface appears to have been scraped nearly smooth by gnawing, and the rock is less crumbly than the Jasper sample. The gnawed surface is less weathered than in the Jasper County sample, and tooth marks are comparatively larger. Approximately 35% of measured marks are ca. 1.8–2.0 mm single and 3.4–5.5 mm paired width and correspond most closely in size to *Sciurus niger* (fox squirrel) incisors. Another 35% of measured marks are relatively large, *ca.* 3.4–4.8 mm single and 5.5 mm paired width, and match *Marmota monax* (woodchuck) incisors (Table 1). Smaller marks of *ca.* 0.6–0.9 mm single and 1.7–2.1 mm paired width (Fig. 2) may be from smaller fox squirrel individuals and from smaller, mouse-sized species, as in the Jasper County specimen. One pair of marks appears to show a central groove (Fig. 2), which may correspond to the upper incisors of a lagomorph (see Cuffey & Hattin 1965). *Sylvilagus floridanus* (eastern cottontail) is the most likely species to occur in Monroe County, and may have produced this pair of marks.

Identifications of gnawing taxa for the two Indiana carbonate-rock specimens are estimates at best. Some of the marks measured in this study fall into the size range of *Sylvilagus floridanus* lower incisors, which would look exactly like rodent incisor marks because they lack the central groove of rabbit upper incisors. However, aside from one set of marks on the Monroe County specimen described above, none of the marks shows distinct central grooves, and all are assumed to have been made by rodents. Unequivocal correlation of species to tooth marks is probably impossible, as the soft, crumbly limestone does not provide sharp distinction of marks; and many Indiana rodents share roughly the same range of tooth size. Additional research, such as live-trapping or analysis of carnivore scat and owl pellets from the two specimen localities could provide a cross-section of local rodent populations and aid in identification of tooth marks.

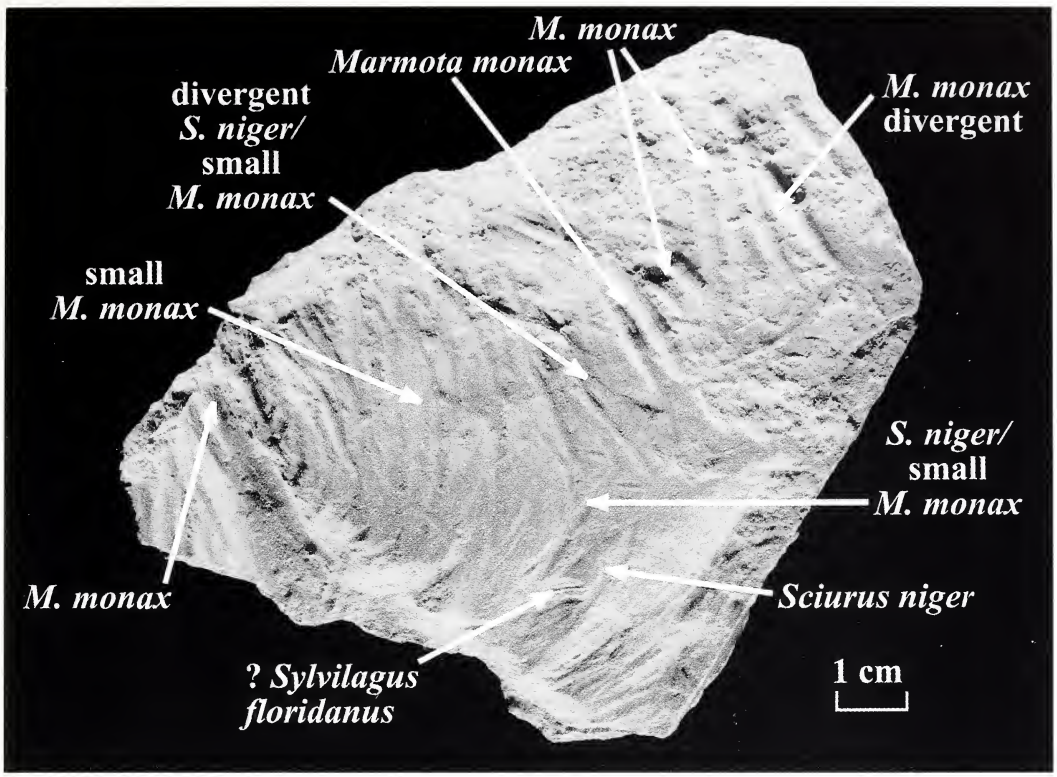

Figure 2.—Ramp Creek limestone specimen (middle Mississippian) from Monroe County, Indiana, with best-preserved tooth marks denoted by labels and with approximate identifications of species. Note central grooves in tooth marks identified as possibly those of the eastern cottontail.

Preliminary observations of rock-gnawing.—Three female *Rattus norvegicus* (domestic Norway rats – relatively recent immigrants to the United States) were kept to see whether captive rodents will gnaw on rocks, and if so, how often. The rats were approximately three weeks old when obtained. They were fed a diverse diet, including fruits, vegetables, grain cereal and rat pellets. If gnawing on various foods is sufficient to wear down incisors, as implied in Zuri et al. (1999), rat pellets and seeds are hard enough to serve this purpose for captive rodents. The pellets are also fortified with vitamins and minerals, including $CaCO_3$, so that the rats' diet had no severe deficiencies. One piece each of the Jasper and Monroe County rock specimens was placed in the rats' cage. Within the first few weeks, the rats left tooth marks on both rocks.

Gnawing occurred at night, for the rats slept throughout the day and were never observed gnawing the rocks. They gnawed selectively on corners and along edges of the specimens. On the Jasper sample they gnawed heavily on one relatively weathered side, and not at all on the other sides. After these first few weeks, no more new tooth marks were visible, and the rock surfaces which had been gnawed began to wear smooth from the rats' climbing over the rocks. Whereas they stopped gnawing the rocks, the rats often grated their upper incisors against the lowers, a habit common among caged rodents, and probably wild ones, that serves to hone the incisors and keep them worn down (Howard & Smith 1952). They also gnawed the bars of the cage.

In May 1999, a piece of Plattsmouth Limestone from the University of Kansas campus in Lawrence was placed against the wall of an apartment building just outside of campus, to see whether any wild rodents would chance to come and gnaw on it. Within a few days, a row of tiny tooth marks was observed along one sharp edge of the rock (Fig. 3). The tooth marks are in the size range of such small rodents as *Peromyscus leucopus* and *Mus mus-*

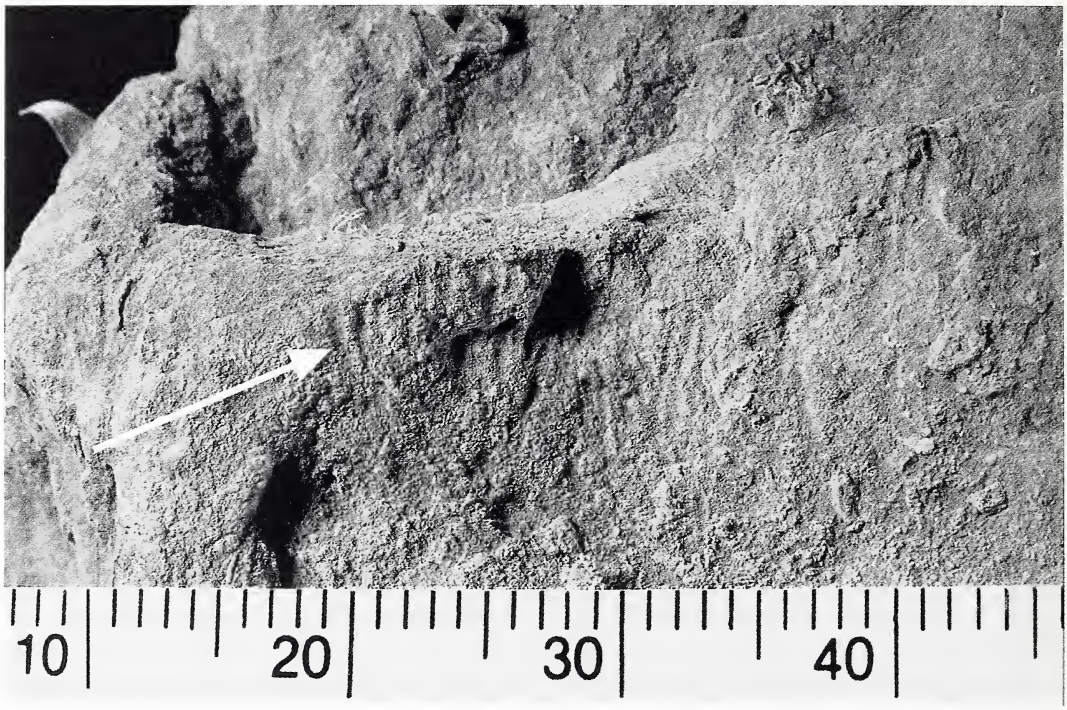

Figure 3.—Sample of Plattsmouth Limestone (Pennsylvanian) from the University of Kansas campus, showing tooth marks left by a mouse-sized rodent.

culus, two species likely to live near human dwellings (Mumford & Whitaker 1982).

DISCUSSION

Rock-gnawing by rodents may be more common than has been assumed. Unless rodents gnaw repeatedly at one specific rock, their tooth marks are likely to be dispersed among many rocks and easily missed, especially if they are quickly erased by weathering. However, rock-gnawing is occasionally observed in the wild as a routine event. Karl W. Leonard (pers. commun. 1997) reported several instances in which *Sciurus niger* gnawed on Silurian Lockport Limestone at a corner of the Geology building on the campus of Kansas State University in Manhattan, Kansas. It is possible that the rock samples from Indiana were likewise visited on separate occasions.

Based upon preliminary observations, captive *Rattus norvegicus* gnaw preferentially along edges and on freshly exposed, relatively crumbly surfaces. Although rock and other hard substances abrade rodent incisors quickly (Burns et al. 1989), the fact that the rats barely used the rock for a long period of time indicates that it was not needed to grind down incisors, at least not on a regular basis. This is particularly evident because, assuming that these activities are to wear down teeth and are not simply due to boredom, the rats continued to gnaw the cage bars and grate their teeth long after they stopped using the rock. Whether only one individual rat produced all the tooth marks, or whether gnawing activity to obtain calcium or magnesium would increase due to pregnancy and/or lactation, are among questions remaining to be addressed using captive rats. Whether the piece of Plattsmouth limestone sample placed outdoors and gnawed by a wild, mouse-sized rodent was simply put in a convenient spot, or attracted the rodent for physical or nutritional needs, remains uncertain.

Rodents may gnaw on rocks for various reasons, including need for minerals, need to wear down the teeth, or need to release stress. Several records show that rodents, lagomorphs and artiodactyls derive minerals directly from rocks. *Sciurus niger* and *Marmota*

monax, both of which may have produced tooth marks on the Indiana rocks, are known to lick salt (NaCl) from roadsides during springtime in southern Indiana (Weeks & Kirkpatrick 1978; Mumford & Whitaker 1982). Presumably, however, the only minerals a rodent could obtain from the Jasper and Monroe County specimens are calcium, magnesium and possibly the clay minerals illite and kaolinite. *Sylvilagus floridanus* may eat clay soil on occasion (Mumford & Whitaker 1982), and *Sylvilagus audobonii* is known to have gnawed extensively on Ca-rich but Si-poor chalky limestone (Cuffey & Hattin 1965). *Neotoma floridana* (wood rat), *Hystrix* sp. (African porcupine) and *Geomys bursarius* (eastern pocket gopher) store and gnaw on bones, most likely to gain calcium, sodium, and phosphorus (Smith 1948; Duthie & Skinner 1986; Richards & Munson 1988; Gow 1992). Small rodent gnaw marks are common on accumulated fossil bones in deposits such as sinkholes, which suggests that rodents specifically seek calcium and other minerals for certain dietary needs.

The Jasper and Monroe County rocks are dominated by the minerals calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) and would be good sources of calcium and magnesium, thus possibly functioning as rodent "licks" similar to those reported by Jones & Hanson (1985) and Peterson (1955) for artiodactyls. Deer and elk licks, in particular, are rich in calcium and magnesium, which are leached from limestones into the soil (Jones & Hanson 1985). However, studies on *Sciurus niger* and *Marmota monax* in southern Indiana (Weeks & Kirkpatrick 1978) show that these species seek sodium much more frequently than they seek calcium and magnesium.

Nutritional needs probably vary among species, individuals and environments. For example, "salt drives" in *Sciurus niger* and *Marmota monax* are highest in springtime (Weeks & Kirkpatrick 1978). Calcium and magnesium may also be more sought after in springtime. Plants growing in carbonate soils, such as those which occur abundantly in Indiana, are naturally enriched in calcium (Jones & Hanson 1985), and perhaps in magnesium. *Marmota monax* eats mainly leaves and stems of plants and may derive much of the calcium and magnesium in its diet from those plants during their growing season. Upon emerging from hibernation in early spring when plants are scarce, *M. monax* may have a calcium/magnesium deficiency which could be compensated for by gnawing carbonate rocks. *Sciurus niger* is not primarily a plant-eater, yet it and *Tamias striatus* may still have calcium/magnesium deficiencies during the winter and early spring months. In addition, gravid or lactating females and growing juveniles may require larger amounts of these minerals than other individuals.

Alternatively, rodents gnawed the Indiana rocks to help wear down continually growing incisors. Observations of captive *Rattus norvegicus* seem to suggest that a rock is not required to wear down teeth on a routine basis, if the rodent habitually eats hard foods. Cuffey & Hattin (1965) discount gnawing to wear down teeth based on the softness of their gnawed chalk sample, which contained only about 1% SiO_2. On the other hand, Gow (1992) observed *Hystrix* sp. gnawing on siltstone containing >1% calcium, which was "like a soft talc" and "easily scored by a fingernail," and suggested that the siltstone could serve as a fine abrasive polish for teeth. Limestone typically has a hardness of about 3. The enamel of rodent incisors contains iron and is therefore harder than the enamel of most mammal teeth. Thus, most carbonate rocks are probably too soft to wear down rodent incisors appreciably. However, as the Indiana samples contain *ca.* 20% SiO_2, they may provide a fine abrasive to help hone incisors. In any case, rodents gnawing these Indiana rocks probably subjected their lower incisors to wear, due to the relatively great amount of SiO_2 in the samples.

Why several different species selected the same Rockford and Ramp Creek samples for gnawing is an intriguing question. Both specimens have suffered considerable weathering such that the rock surfaces are soft and somewhat crumbly. Such a condition would make gnawing, especially for nutrients, an easy process and could explain why more than one species chose each of these rocks for its nutritional or tooth-wear needs. It is also probable that, once a rodent had gnawed and left its scent on the rock exposure, conspecifics and other species would be likely to approach the rock so as to leave their scent as well and gnaw at the rock, which would be covered with salty deposits from the other rodents.

Thus far, no studies of this type of behavior have been made; and further study is needed to determine the reasons why wild rodents gnaw on rocks, and the role carbonate rocks play in the ecology of Indiana rodents.

CONCLUSIONS

A dolomitic limestone sample from Monroe County and a calcitic dolostone sample from Jasper County, Indiana, were gnawed extensively by several species of rodents and possibly one lagomorph. Species identified to tooth marks on the rocks include *Marmota monax*, mouse-sized species, and possibly *Sciurus niger* and *Sylvilagus floridanus* (Monroe County specimen), and *Sciurus ?carolinensis*, *Tamias striatus* and mouse-sized species (Jasper County specimen). The reason for the gnawing behavior is still uncertain. We propose that the gnawed carbonates could have served as a source of calcium and/or magnesium. The rocks also contain significant amounts of abrasive SiO_2, which could help wear down rodent incisors. These needs may vary with specific habitat conditions, and further studies may demonstrate use of cacium and magnesium by pregnant or lactating rodents and rodents in seasonally or perpetually mineral-deficient areas. Preliminary observations show that both captive and wild small rodents readily gnaw on carbonate rocks placed in their environment. The rock-gnawing habit may thus extend to rodents in a wide variety of habitats, be a more common behavior than previously supposed, and be worthy of future experimental investigation.

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