

A FOSSIL MARMOT FROM NEW MEXICO AND ITS CLIMATIC SIGNIFICANCE.

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ABSTRACT. Fossil marmot bones found at an altitude of 5900 feet on New La Bajada Hill, New Mexico, belong to a species now living near and above timber-line in the Sangre de Cristo Mountains. A lowering of life zones of 4000 feet at some time in the past is necessary to explain the presence of this fossil marmot. This lowering of life zones presumably occurred during the late Wisconsin. So large a depression is difficult to reconcile with previous estimates of the magnitude of climatic changes in this area during the Wisconsin. However, it is corroborated to some extent by finds of fossil marmots at other localities.

Ancient landslides, now inactive, at several localities in the Southwest have been attributed to a period of greater humidity and intensified frost action. Similar inactive landslides occur at New La Bajada Hill. The inference that they, too, were formed under climatic conditions now existing only at higher altitudes receives support from this find of marmot bones in dust-filled cracks formed when the landsliding was active.

INTRODUCTION.

THE marmot is now represented in New Mexico¹ by a single species, the dusky marmot, *Marmota flaviventris obscura* Howell. This animal, like others of the *M. flaviventris* group, has a rather restricted range. It is found "on the upper slopes of high peaks in northern New Mexico and southern Colorado," and "occurs in Hudsonian and upper Canadian Zones from about 9600 feet altitude to the summits of the peaks."² Its most southerly occurrence is in that portion of the Sangre de Cristo Mountains called the Pecos Mountains. Here Bailey found it to be "common from a little below timber-line at 11,400 feet to the highest peaks in that range."³ In the past, however, its range has been much more extensive. Fossil bones referred to this species have been reported from caves in the Manzano, Tularosa, and Guadalupe Mountains in New Mexico, and near Sonoita, Arizona. These localities are not only far south of its present range, but also at far lower

¹ Bailey, Vernon: 1931, Mammals of New Mexico, U. S. Dept. Agriculture, Bureau of Biol. Survey, North American Fauna No. 53, pp. 131-133.

² Howell, A. H.: 1915, Revision of the American Marmots, U. S. Dept. Agriculture, Bureau of Biol. Survey, North American Fauna No. 37, p. 53.

³ Bailey: *op. cit.*, p. 131.

altitudes. (Fig. 1.) The fossil material here recorded is also from a locality outside the known range of the species, and at a far lower altitude. It is obvious that, unless the habits of

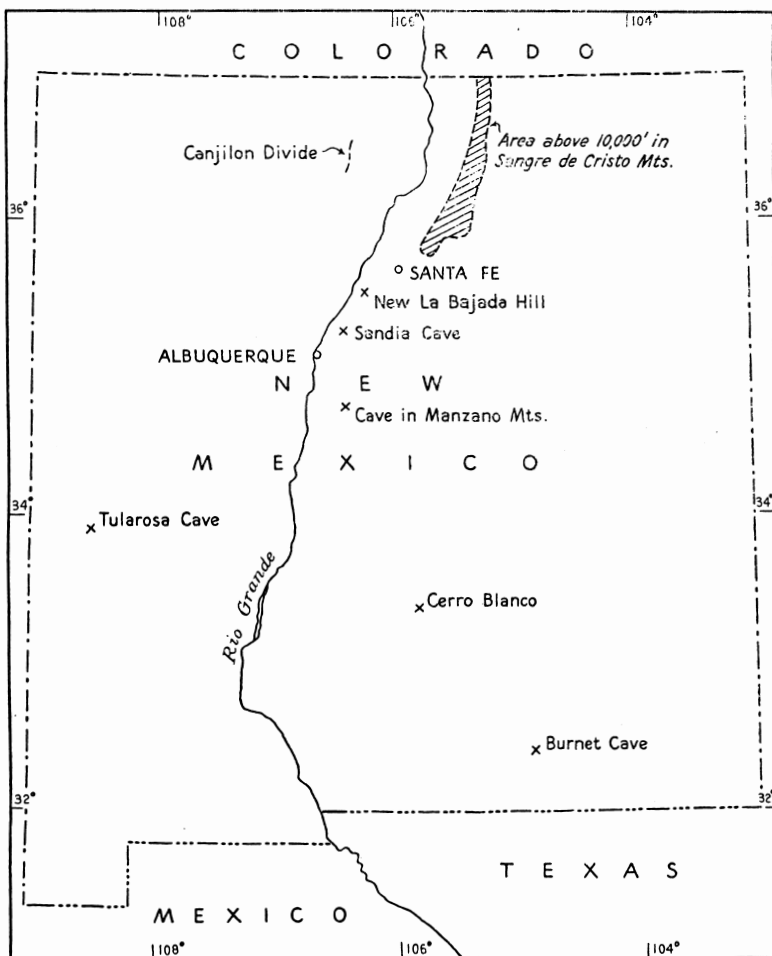


FIG. 1. Index map of New Mexico, showing present range of the dusky marmot and localities from which it is reported as a fossil. Other localities mentioned in the text are also shown.

the animal have changed radically in recent times, there must have been a very different distribution of the life zones, and therefore of the climatic zones of New Mexico at some time or times in the past.

DESCRIPTION OF THE LOCALITY.

About twenty-five miles southwest of Santa Fe, U. S. Highway 85 leaves the broad, grassy plain which slopes westward from the Sangre de Cristo Mountains, and descends a rough escarpment some 300 feet high to the valley of Galisteo Creek. This is the La Bajada escarpment, and the long grade on the road is usually called New La Bajada Hill. The escarpment is capped by a flow of quartz basalt overlying 20 to 50 feet of alluvium. The alluvium rests on an erosion surface which locally bevels rocks of Cretaceous and Tertiary age.

A striking feature of the escarpment are the great landslide masses which mark its western slope and base. They are of relatively ancient date, as many of them are dissected by deep and continuous gullies. Moreover, landslides no longer form. The scarp is now retreating by the slow and unspectacular process of the fall of individual blocks as the lava cap is undermined. In places the slopes of the scarp and of the ancient landslides are mantled by a talus of basalt fragments derived from these individual falls. Quantitatively, this process is of only minor effect. The position of the edge of the lava has not greatly changed from that which existed at the close of the period of landsliding.

Where Highway 85 cuts through the basalt, the contact of the lava with the underlying alluvium is exposed for a distance of 225 feet. The alluvium in this locality is a fine-grained, pink, calichified arkose about 25 feet thick. Its upper six inches are bright red, presumably because of baking by the lava, and contain abundant small, tubular concretions of lime. The basalt is here about 15 feet thick and is divided by rude columnar jointing into blocks two feet or more across. Although the original surface of the flow has been entirely destroyed by weathering and erosion, its lower portion is almost unweathered. The bottom of the flow is a discontinuous layer of rubble as much as two feet thick, which is in most places firmly cemented with caliche.

At one place in the road-cut, the layer of rubble is absent for a short distance (Fig. 2). Here there appears to have been an open cavity beneath the flow. This cavity was six feet wide, one foot high, and at least three feet deep. It may have been left open under the advancing flow, or it may have been excavated in the rubble later by small animals. This cavity was filled with fine, brown dust containing numerous basalt frag-

ments separated from the local rubble. Disarticulated bones are distributed at random throughout the deposit, and it follows that they were emplaced during its accumulation. The dust may be followed upward in opened cracks separating the rough basalt columns. These cracks vary from tiny slits to openings six inches wide, and were formed after the lava had cooled. The dust has a slight lime content, and the bones are coated with powdery calcium carbonate. This incipient calichification is obviously later than the accumulation of dust.

Elsewhere in the road-cut, fine, brown dust occurs in the interstices of the basaltic rubble, and in opened cracks between the rough lava columns. Similar accumulations of dust in

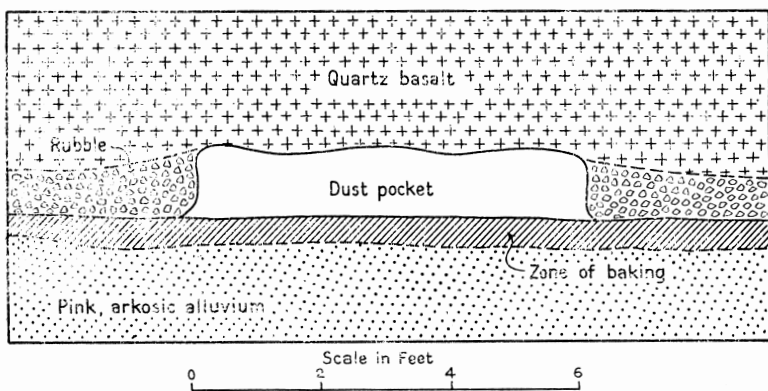


FIG. 2. Diagrammatic sketch of the fossiliferous dust pocket exposed in a road-cut at New La Bajada Hill, New Mexico.

rubble and in opened cracks have been observed at six favorable localities along the La Bajada escarpment, within a distance of three miles north and two miles southeast of the fossiliferous dust pocket. The formation of cracks and the accumulation of dust are therefore general phenomena. Although no fossils were found in these other places, it is probable that all of the dust deposits are of the same age.

The cracks now filled with dust opened as an incident of an incipient stage of the major landsliding. Such cracks would not form at any great distance behind the escarpment. Through them, dust accumulated by filtering down from the surface. That the many bones found were introduced by merely falling into a crack is improbable. It seems more likely that animals had access to the cavity through an opening on

the escarpment. Thus it is implied that, at the time the cracks formed and filled, the edge of the escarpment had a position near that which it has since occupied. At one locality southeast of New La Bajada Hill, calichification in the dust-filled rubble merges without perceptible break with the caliche or soil zone on a small landslide mass. Here dust and landslide are older than the process of calichification. The implication is that the period of dust accumulation occurred at the close of, or just after, the period of landsliding.

At various times in the summers of 1940 and 1941, the fossiliferous dust pocket was excavated, and bones and bone fragments were collected. The late Dr. Glover M. Allen of Harvard University, with his usual generosity, identified the following forms:

Marmota flaviventris obscura (dusky marmot)

Thomomys sp. (pocket gopher)

Peromyscus sp. (white-footed mouse)

Bison cf. *bison*

a squirrel about the size of a red squirrel

a bird about the size of a grouse

One endocarp of *Celtis* sp., identified by Dr. W. C. Darrah of Harvard University, was also found.

Of these forms, only the marmot seems to be significant. Much skeletal material of this rodent was found, including three right rami and four left innominate bones, representing at least four individuals. One or two individuals might stray a great distance from their natural habitat, but that four migrants or wanderers should die in this place is unlikely. Hence, the fossil record strongly suggests that marmots once lived at this locality.

CLIMATIC IMPLICATIONS.

The present-day marmots of the Sangre de Cristo Mountains "often burrow under large boulders in the parks and meadows, but more often live in fathomless piles of broken rock along the base of cliffs, or in seams and crevices of the cliffs themselves."⁴ Their diet "consists entirely of green vegetation"⁵ of all types. A small cave on the rough basalt escarpment would make an ideal home for such an animal. The present

⁴ Howell: *op. cit.*, p. 55.

⁵ Bailey: *op. cit.*, p. 132.

sparse grass and coarse shrubs of the area, however, are green only in the spring and after summer rains. Presumably such vegetation would not support marmots. If they once lived here, it is necessary to postulate a different climate, which would support a richer vegetation. Climatic changes are known to have occurred in this area during the Pleistocene, as glaciers formed at least three times in the nearby Sangre de Cristo Mountains during Wisconsin time.⁶

If the environment at New La Bajada Hill once corresponded to that of the present habitat of the New Mexican marmot, a major lowering of life zones is demanded. Bailey reports the present range of the marmot as above 11,000 feet in the Sangre de Cristo Mountains. The specimens studied by Howell, however, include a series taken near Osier, Colorado, at an altitude slightly above 9600 feet. As Osier is only 100 miles north of Sante Fe, it may be that Bailey's limit is too high, and that the marmot may range down as low as 10,000 feet in the Sangre de Cristo Mountains. The altitude of the road-cut at New La Bajada Hill, however, is only about 5900 feet. A lowering of life zones of at least 4000 feet is indicated.

Such a lowering of life zones should reflect a regional depression of climatic zones in magnitude as well as direction. Such a regional lowering of climatic zones is greater than any previously suggested. The effect of general climatic change may have been exaggerated along the La Bajada escarpment, which even at present provides a special environment. Its rough slopes now support a juniper-brush-grass association different from the grass association of the plains above or below. The rocky breaks, with juniper, continue south and east to Los Cerrillos, a small group of hills reaching a maximum elevation of 7000 feet, and north and west across the Rio Grande to the east flanks of the Jemez Mountains. It is possible that the fauna of these two areas might migrate along the escarpment at elevations below their normal range. But if the natural habitat of the marmot once existed at 6500 feet in Los Cerrillos, or even higher in the Jemez Mountains, the necessary general depression of life and climatic zones is still at least 3000 feet. This is at best a minimum figure, and it would seem that the actual shift must have been larger.

⁶ Ray, L. L.: 1940, *Glacial Chronology of the Southern Rocky Mountains*, Bull. G. S. A., Vol. 51, pp. 1851-1918.

The landslide masses along the La Bajada escarpment are not forming under present conditions, and the dissection of many of them indicates that their age may be considerable. Reiche⁷ has suggested that the Toreva blocks of northeastern Arizona were formed during the more humid climate of the Pleistocene, and Strahler⁸ makes the same inference for those of the Lees Ferry area. Smith⁹ believes that twice during the Pleistocene greater humidity and frost action produced the even more remarkable landsliding at Canjilon Divide, sixty miles north of New La Bajada Hill (Fig. 1). On the same grounds, it is believed that the landsliding at New La Bajada Hill dates from the Pleistocene. The climatic change thereby postulated is similar to that which would provide an environment suitable to the marmot.

OTHER LOCALITIES.

The cave in the Manzano Mountains from which Howell¹⁰ reports marmot bones is at an altitude of approximately 9000 feet, which requires a lowering of life zones of only 1000 feet. The bones were collected by a local rancher, and nothing is known of their mode of occurrence.

Tularosa Cave, in the Tularosa Mountains, has an altitude of about 7000 feet. The fauna reported from it by Lyon,¹¹ in which the marmot is represented by a single skull fragment, is chiefly of Upper Sonoran character. The material was obtained by Hough¹² from a débris heap behind prehistoric Indian dwellings. He implies that the débris is stratified, but he did not record the position of the marmot skull in it. As the upper levels of the débris contain Indian refuse, he assumes that the entire deposit, and its included fauna, were contemporary with Indian habitation. The association of a marmot with an Upper Sonoran fauna, however, or with human occupa-

⁷ Reiche, Parry: 1937, The Toreva Block—a Distinctive Landslide Type, *Jour. Geol.*, Vol. 45, pp. 538-548.

⁸ Strahler, A. N.: 1940, Landslides of the Vermilion and Echo Cliffs, Northern Arizona, *Jour. Geomorph.*, Vol. 3, pp. 285-301.

⁹ Smith, H. T. U.: 1936, Periglacial Landslide Topography of Canjilon Divide, Rio Arriba County, New Mexico, *Jour. Geol.*, Vol. 44, pp. 826-840.

¹⁰ Howell: *op. cit.*, p. 55.

¹¹ Lyon, M. W.: 1907, Mammal Remains from Two Prehistoric Village Sites in New Mexico and Arizona, *Proc. U. S. Nat. Mus.*, Vol. 31, pp. 647-649.

¹² Hough, Walter: 1914, Culture of the Ancient Pueblos of the Upper Gila Region, New Mexico and Arizona, *Bull. U. S. Nat. Mus.*, Vol. 87, 139 pp.

tion, has not been demonstrated. It is possible that the skull was imported to the cave by Indians. Howell¹³ states that the fragment is specifically unidentifiable, but assumes that it indicates the former presence of *M. flaviventris obscura* in the Tularosa Mountains. Eagle Peak, the highest point in that range, has an altitude of 9800 feet, and altitudes over 9000 feet are fairly common. A minimum lowering of life zones of 1500 feet would provide an environment suitable to the dusky marmot at these highest points, where they would be available to contemporary hunters, or to Indian collectors of fossil bone. If marmots once lived in the vicinity of Tularosa Cave, a shift of 3500 feet is required.

Burnet Cave, on the east slope of the Guadalupe Mountains, is at an altitude of 4600 feet. In it, a large fossil fauna was found in association with hearths and with one Folsom-like point. Of the forty-three mammals reported by Schultz and Howard,¹⁴ ten are extinct. Of the species now living, nearly half are not found in the Guadalupe Mountains today, although found elsewhere in New Mexico at higher altitudes. Most of these are characteristic of the Transition Zone. Marmot bones, representing several individuals, are indistinguishable from those of the modern *M. flaviventris obscura*. The number of individuals represented makes it unlikely that they were introduced from any great distance. The marmot, however, as an Hudsonian form, is an aberrant element in the fauna. It may have been introduced by human agency from higher altitudes in the mountains. The crest of the range does not exceed 6500 feet in this area. El Capitan, fifty miles to the south in Texas, has an altitude of 8700 feet. The former presence of marmots in the Guadalupe Mountains, far south of the Pecos Mountains, would indicate a lowering of life and climatic zones of 4500 feet. If the bones were imported from Texas by the pre-historic inhabitants of the cave, which is somewhat less likely, 2500 feet would be a sufficient minimum lowering.

M. flaviventris has also been identified in the fossil fauna of Papago Spring Cave,¹⁵ near Sonoita, Santa Cruz County,

¹³ Howell: *op. cit.*, p. 55.

¹⁴ Schultz, C. B. and Howard, E. B.: 1935, The Fauna of Burnet Cave, Guadalupe Mountains, New Mexico, *Proc. Acad. Nat. Sci. Phila.*, Vol. 87, pp. 273-298.

¹⁵ Colbert, E. H. and Chaffee, R. G.: 1939, A study of *Tetrameryx* and Associated Fossils from Papago Spring Cave, Sonoita, Arizona, *Amer. Mus. Novitates* No. 1034, 21 pp.

Arizona. It is suggested that the fossil fauna may be associated with artifacts, but this association is not clearly demonstrated. As far as known, marmots do not now live in Arizona. The nearest living representative of that group is the dusky marmot of New Mexico. The altitude of Papago Spring Cave is about 4800 feet. Old Baldy Peak, in the nearby Santa Rita Mountains, has an altitude of 9400 feet. A lowering of life zones of 2000 feet would provide an environment suitable to the dusky marmot on this high summit.

GENERAL SHIFT OF CLIMATIC ZONES IN THE PLEISTOCENE.

Klute¹⁶ suggests that the climatic snow-line in the Sangre de Cristo Mountains was lowered about 2000 feet during Wisconsin time. He expresses this relationship in curves showing the altitude of the present and Wisconsin snow-lines along the meridian of the Southern Rocky Mountains (Fig. 3). The

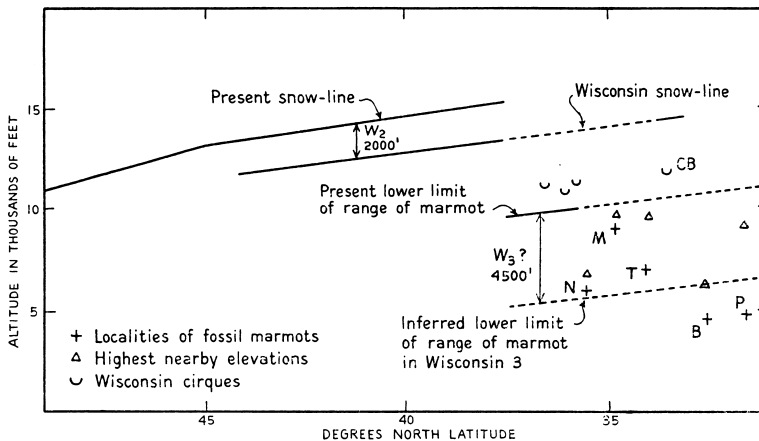


FIG. 3. Comparison of the lowering of the range of the dusky marmot to the depression of the climatic snow-line suggested by Klute; all data projected on the 105th meridian. Localities indicated by letter: B, Burnet Cave; CB, Cerro Blanco; M, cave in the Manzano Mountains; N, New La Bajada Hill; P, Papago Spring Cave; T, Tularosa Cave.

climatic snow-line is the lower limit of everlasting snow in an ideal climate which is not influenced by topography. It is thus distinguished from, and higher than, the orographic snow-line, the lower limit of those isolated patches of snow which owe

¹⁶ Klute, Fritz: 1928, Die Bedeutung der Depression der Schneegrenze für eiszeitliche Probleme, Zeit. für Gletscherkunde, Vol. 16, pp. 70-93.

their preservation to the favorable influence of topography. It follows that any change in the position of the climatic snow-line will be reflected by similar changes in the position of the orographic snow-line, and of all the climatic and life zones. Klute's curves, therefore, give us a graphic picture of the shift in climatic and life zones in New Mexico during Wisconsin time.

The glaciation of Cerro Blanco, 175 miles south of the Sangre de Cristo Mountains, has recently been established by Smith and Ray.¹⁷ The cirque-floor on Cerro Blanco has an altitude of 11,500 feet. Ray¹⁸ has shown that the present orographic snow-line in the Sangre de Cristo Mountains may lie as much as 3000 feet below the climatic snow-line proposed by Klute, and that a similar difference obtained during the Wisconsin. Three cirques reported by Ray are plotted in Fig. 3 to show this relationship. Assuming that the same difference occurred at Cerro Blanco, the Wisconsin climatic snow-line would have an altitude of 14,500 feet. Klute's curve has been extended to this point.

The lower limit of the present range of the dusky marmot (*M. flaviventris obscura*) is also shown in Fig. 3 as an inclined line from 9600 feet at Osier to 10,000 feet in the Pecos Mountains. For the purpose of comparison, it has been arbitrarily extended southward at the same gradient. The relative positions of those localities from which fossil marmots are reported, and of the highest nearby elevations, have been projected to the same meridian. It is immediately obvious that the lowering of the range of the dusky marmot is far greater than that suggested by Klute for the climatic snow-line.

Of the five substages of the Wisconsin established by Ray¹⁹ in the Southern Rocky Mountains, Klute's curve presumably refers to Wisconsin 2, which is the stage heretofore called "Wisconsin." At other times during the Pleistocene, the shift of climatic zones may have been greater or less. However, the intensity of glaciation in Wisconsin 1 seems to have been about the same as that in Wisconsin 2, and glaciation in the later substages of the Wisconsin appears to have been less severe.²⁰

¹⁷ Smith, H. T. U. and Ray, L. L.: 1941, Southernmost Glaciated Peak in the United States, *Science*, n. s., Vol. 93, p. 209.

¹⁸ Ray, L. L.: *op. cit.*, pp. 1911-1912.

¹⁹ Ray, L. L.: *op. cit.*

²⁰ *idem.*, p. 1909.

Bryan²¹ has correlated the deposits of Sandia Cave, about twenty miles south of New La Bajada Hill (Fig. 1), with the climatic change of Wisconsin 3. A lowering of the vegetative zones of only 1000 feet is a sufficient minimum amount to explain the deposition of calcium carbonate and limonite by water dripping in a cave that is now dry. The actual shift was presumably somewhat larger.

Unfortunately, the positions of the several occurrences of fossil marmots in the complex chronology of the Pleistocene is not accurately known. The dust pocket at New La Bajada Hill and its contained bones are close in date to landsliding produced by the most recent effective climatic change. Although the landslides have been dissected, their form is still characteristic and the edge of the escarpment has retreated only a slight distance since their formation. These facts indicate that their antiquity is moderate. The glacial forms of the substage Wisconsin 1 in the Southern Rocky Mountains have been largely obliterated by later weathering and erosion. The distinct and only slightly dissected landslides therefore seem too fresh for Wisconsin 1, and presumably were formed in Wisconsin 2 or 3. The fauna of Burnet Cave is associated with a Folsom-like point. This is not a typical Lindenmeier point, but points not far different occur with Lindenmeier types. If it be taken to represent a culture of the same age as Lindenmeier, the fauna of Burnet Cave may be correlated with the climatic change of Wisconsin 3.²² If this imperfect dating be reliable, the lowering of life zones in Wisconsin 3 ranged between a minimum of 2500 feet and a more probable figure of 4500 feet in the Guadalupe Mountains.

CONCLUSION.

To explain the former presence of marmots at New La Bajada Hill requires a regional lowering of climatic zones of over 3000 feet, even if it is assumed that this change was here exaggerated by local topographic conditions. To explain the former presence of marmots in the Guadalupe Mountains, a similar shift of 2500 to 4500 feet is required. Other occur-

²¹ Bryan, Kirk: 1941, Correlation of the Deposits of Sandia Cave, New Mexico, with the Glacial Chronology, *Smithson. Misc. Coll.*, Vol. 99, no. 23, pp. 45-64.

²² Bryan, Kirk and Ray, L. L.: 1940, Geology of the Lindenmeier Site, Colorado, *Smithson. Misc. Coll.*, Vol. 99, no. 2, 76 pp.

rences of fossil marmots are not critical. It is strongly implied that climatic changes in New Mexico during the Wisconsin may have been greater than formerly supposed. The lowering of climatic zones during the substage Wisconsin 3 may have been as great as 4500 feet. The find here recorded has its present importance as a guide-post to further inquiry and as a confirmation of the former presence of an Hudsonian climate at low altitudes, as already postulated by several authors to explain ancient landslides.

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