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CONTENTS

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# An Unusual Specimen of *Allosaurus* from Southeastern Utah

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ABSTRACT

An adult specimen of *Allosaurus fragilis* (BYU 2028) was recovered in the 1970's by James Jensen and Kenneth Stadtman, both of Brigham Young University, from southeastern Utah. It was described by Lisak (1980), who's description is summarized here in light of later research on the allosaurid skull by Witmer (1997) and Currie and Zhao (1993). BYU 2028 represents an *Allosaurus* with some unusual characters. It possesses an expanded nasal crest and increased paranasal pneumaticity that are unusual for the genus. Therefore, this partial skull is used to more fully document the range of variation of these characters in *Allosaurus*.

## INTRODUCTION

A moderate-sized partial skull of *Allosaurus* (BYU 2028) was discovered by Gene Day of the U. S. Bureau of Land Management in the mid-1970's in the of Salt Valley of the Paradox Basin (Moab-10 Quadrangle, T24S, R20E), near Moab, Utah (Figure 1) (Stadtman, pers. com., 2001). The specimen was found in a conglomeratic boulder that had rolled from a ridge on the west side of Mill Canyon Wash in the region of Mill Creek Dinosaur Trail (Lisak, 1980). It was collected by James Jensen and Kenneth Stadtman, who determined that it was derived from the upper part of the Brushy Basin Member of the Morrison Formation (Stadtman, pers. com., 2001).

Lisak (1980) referred this specimen to *Allosaurus* cf. *fragilis*. It consists of both sides of a partial skull (Figures 2–4) and both mandibles (Figures 5–6). In general, the left side of the skull is better preserved than the right. The premaxillae, maxillae, nasals, vomer, and fragmentary lacrimals are present in this specimen. The preserved part of the mandibles consists of the dentary, surangular, prearticular, splenial, coronoid, and intercoronoid (=supradentary). Unlike the skull, the right mandible is better preserved than the left. The skull was distorted so that the left premaxilla was displaced anteriorly and medially around the anterior end of the right premaxilla.

Most of the bones are very typical of *Allosaurus fragilis* (Madsen, 1976). There are, however, some unusual characters in BYU 2028 that increase the range of morphological variation for the species. This paper documents the novel cranial variation observed in this single taxon.

*Abbreviations.*—BYU, Brigham Young University, Provo, Utah; DNM, Dinosaur National Monument, Vernal, Utah; MOR, Museum of the Rockies, Bozeman, Montana; OH, Ohio University, Athens, Ohio; UUVP University of Utah Vertebrate Paleontology, Salt Lake City, Utah; UVSC, Utah Valley State College, Orem, Utah.

*Systematic Paleontology*
Dinosauria Owen, 1842
Theropoda Marsh 1881
Carnosauria von Huene 1920
Allosauridae Marsh, 1877
*Allosaurus* Marsh, 1877
*Allosaurus fragilis* Marsh 1877

*Description.*—Some of the information presented here repeats or elaborates upon previous descriptions of this taxon (Lisak, 1980; Madsen, 1976). All descriptions are based on the better preserved left side of the skull. Comparison with bones from Dry Mesa, Cleveland-Lloyd, and Dinosaur National Monument Quarries indicate that most of the Moab *Allosaurus* are typical for *A. fragilis* (Madsen, 1976; Currie and Zhao, 1993). However, a highly ornamented crest is present that is reminiscent of, though

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less exaggerated than that in *Alioramus* (Kurzanov, 1976). Another feature is the increased convexity of the ventral margin of the maxilla and premaxilla. Pneumatization of the maxillary ascending process and paranasal region is more pronounced than would be expected for this species. Pneumatic terminology follows Witmer (1997).

*Premaxilla.*—The left premaxilla (Figure 2) was displaced anteriorly and medially to cover the original joint with the right premaxilla (Lisak, 1980). Unlike many specimens of *Allosaurus fragilis,* the body of this bone is higher than long (Currie and Zhao, 1993). Otherwise, it is typical for *Allosaurus* (Madsen, 1976). The lateral side is smooth, with small, random fenestrae as is the case in most other theropods. Presumably, they serve the same function as proposed for *Sinraptor,* accommodating the subnarial artery and branches of the medial ethmoidal nerve (Currie and Zhao, 1993). There is a vertical anterior margin, so the supranarial process (= ascending nasal process of Madsen, 1976) is inflected at the base. A lateral groove receives the supranarial process of the nasal. Unlike *Sinraptor,* the subnarial process (=maxillary process of Madsen, 1976) does not contact the nasal, so the maxilla is not excluded from the narial opening. Hence, the wall of the vestibular bulla is visible in lateral view, separating the premaxilla from the nasal (Witmer, 1997). The subnarial foramen is typical in size and location for *Allosaurus fragilis* (Madsen, 1976). The contact with the maxilla is vertical below the subnarial foramen, then it slopes back to form the ventral boundary of the subnarial process.

The interdental plates are fused and all about the same height. There are 5 premaxillary teeth or alveoli present. Teeth 3 and 4 are preserved in the right premaxilla. On this side, 1 and 5 are broken at the base. Tooth 4 is significantly shorter than the rest. Tooth 2 is the only one preserved in the left premaxilla. The rest are broken at or near the base. Premaxillary teeth 1 and 2 are somewhat D-shaped in cross-section, becoming increasing oval proceeding from 3 to 4 to 5. The dental carinae are on the lingual side in the first two teeth, then move to the posterior margins of the subsequent teeth.

*Maxilla.*—In most respects, the maxilla (Figure 2) is typical for *Allosaurus* (Madsen, 1976). The lateral surface is rugose anteriorly and immediately above the toothrow as in *Sinraptor* (Currie and Zhao, 1993). Small labial foramina are present above the teeth, accommodating the branches of the superior alveolar nerve and maxillary artery (Currie and Zhao, 1993). There is a well-developed excavation with a smooth surface around the antorbital fenestra. Unlike most specimens of *Allosaurus,* the ventral border is convex. The maxillary fenestra is larger and higher in the ascending process than in *Sinraptor* (Currie and Zhao, 1993), or many other specimens of *Allosaurus* (Madsen, 1976). The lateral surface of the ascending process has a pronounced pneumatic excavation (Witmer, 1997) that is subdivided by a ridge from the posterodorsal corner to the anteroventral corner. The resulting anterior excavation is continuous with a deep groove between the nasal and maxilla that may be equivalent to foramen 4 in *Sinraptor* (Currie and Zhao, 1993). Another pneumatic opening, anterior to the maxillary fenestra, is identified as the promaxillary fenestra (Figure 4) (Witmer, 1997). The premaxilla and nasal exclude most of the maxilla from the margin of the external nares. The end of the ascending process bifurcates at its junction with the lacrimal. The two resulting processes are about the same length.

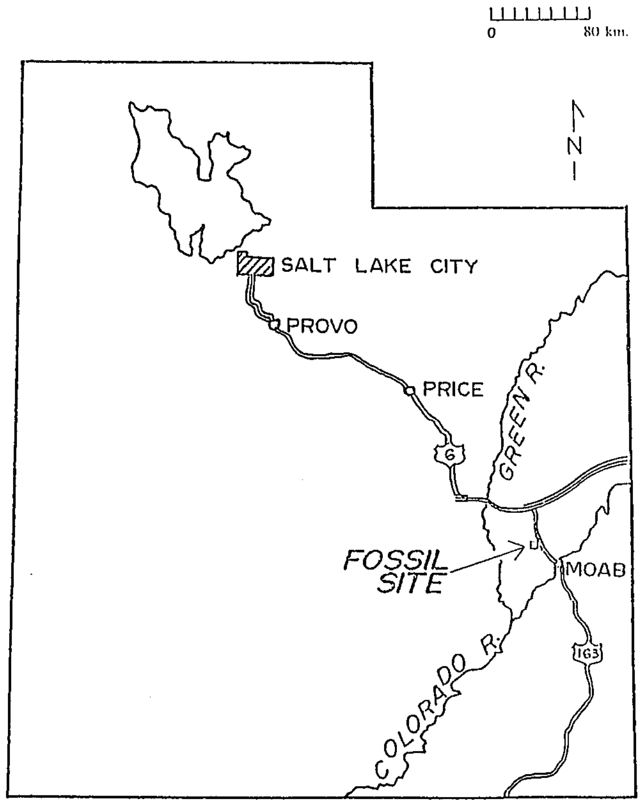


*Figure 1. Locality of BYU 2028 (after Lisak, 1980). Statewide scale equals about 80 km.*

Under the external nares, there is a well-preserved vestibular bulla (Figure 3) (Witmer, 1997). Part of the wall of this bulla can be seen in lateral view separating the subnarial processes of the premaxilla and maxilla. Within the naris, the bulla forms an excavated base of the narial chamber. The bone making up this base is very thin and typically not preserved, although there is a partial base in BYU 5126. Going posteriorly, the bone splits into two horizontal processes medial to the maxillary fenestra. This

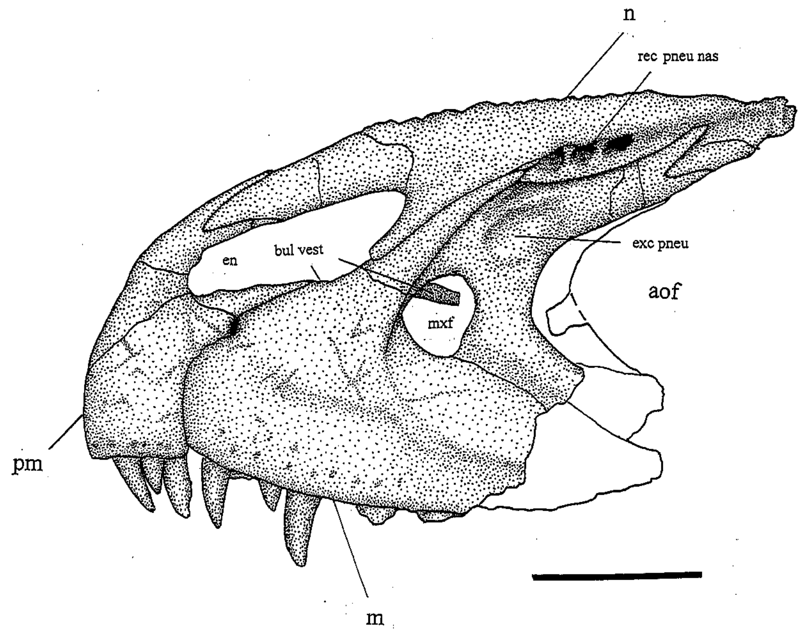


*Figure 2.* Allosaurus fragilis *snout (BYU 2028) in left lateral view. Abbreviations: aof, antorbital fenestra; bul vest, vestibular bulla (bulla vestibularis); en, external nares; exc pneu, pneumatic excavation (excavatio pneumatica); m, maxilla; mxf, maxillary fenestra; n, nasal; pm, premaxilla; rec pneu nas, nasal pneumatic recess (recessus pneumaticus nasalis). Scale bar equals 10 cm.*

process is apparently related to the promaxillary diverticulum between the vestibular bulla and maxillary fenestra (Witmer, 1997).

There are no teeth preserved in the right maxilla, although there is a replacement tooth in the fifth alveolus. In the left maxilla, teeth 1–5 are preserved. The fourth tooth is significantly shorter than the rest.

*Nasal.*—The nasal (Figure 2) is long with a narrow dorsal surface that is distinct from that part contributing to the antorbital fenestra. It is dorsally concave as a result of the presence of an ornamented ridge from the lacrimal to the anterior part of the nasal. This ridge is similar to, but less pronounced, than the one in *Alioramus* (Kurzanov, 1976). The nasal pneumatic recess is expanded so that it has invaded the wall of the nasal and is visible externally. There are three pneumatic openings that interconnect internally in the left nasal and two on the right within the antorbital excavation (Witmer, 1997). The chamber extends anteriorly into the nasal. This development is similar to that seen for *Sinraptor* (Currie and Zhao, 1993). Like other specimens of *Allosaurus,* the nasal splits in the anterior and posterior ends. The posterior end overlays the maxilla and is covered itself by the lacrimal.

*Vomer.*—The vomer can be seen in ventral view. BYU 2028 is only the third specimen, after UUVP 6000 (Madsen, 1976) and MOR 693 (Madsen, pers. com., 2001), where the vomer is preserved in place. Unlike *Sinraptor* where it splits anteriorly (Currie and Zhao, 1983), this element is fused along almost its entire length, except for the posterior end, in BYU 2028 and other specimens of *Allosaurus* (Madsen, 1976). It is long, thin, and anteriorly spatulate as in UUVP 6000 (Madsen, 1976). Posteriorly, this bone is partially concealed in BYU 2028, but forms a vertical plate. The bone was distorted and has been displaced dorsally against the ridge at the base of the promaxillary fenestra.

The frontal and lacrimal are fragmentary, so no new information regarding these bones is available from this specimen.

*Dentary.*—The dentary (Figures 4–5) is similar to that in other specimens of *Allosaurus,* except that the lower margin is more concave, so the thinnest part is in the middle of the bone. As in *Allosaurus* described previously (Madsen, 1976), mental foramina are present on the lateral surface. Other small foramina can be found on the anteroventral end. Like *Allosaurus,* the interdentary symphysis is poorly defined. Posteriorly, the dentary increases in depth. Most of the interdental plates are not visible, as they are covered by a straplike supradentary (=intercoronoid). The dentary is concave at Meckel's groove. On the posterior end of the groove are two foramina, as in *Sinraptor* (Currie and Zhao, 1993). Currie and Zhao (1993) indicate that the upper one accommodates the inferior alveolar nerve and internal mandibular artery. They did not ascribe a function to the lower one.

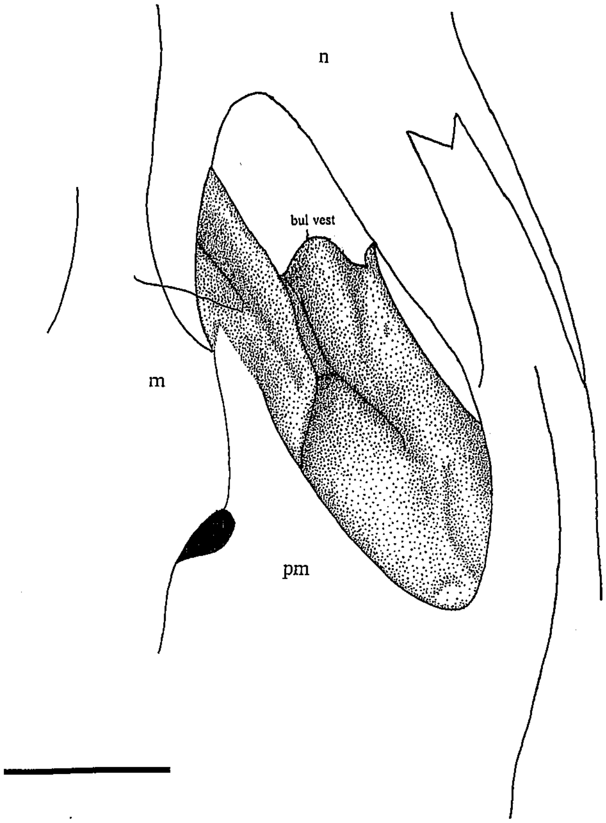


Figure 3. Anterolateral view of dorsal side of vestibular bulla through external naris in BYU 2028. Abbreviations: As in Figure 2. Scale bar equals 5 cm.

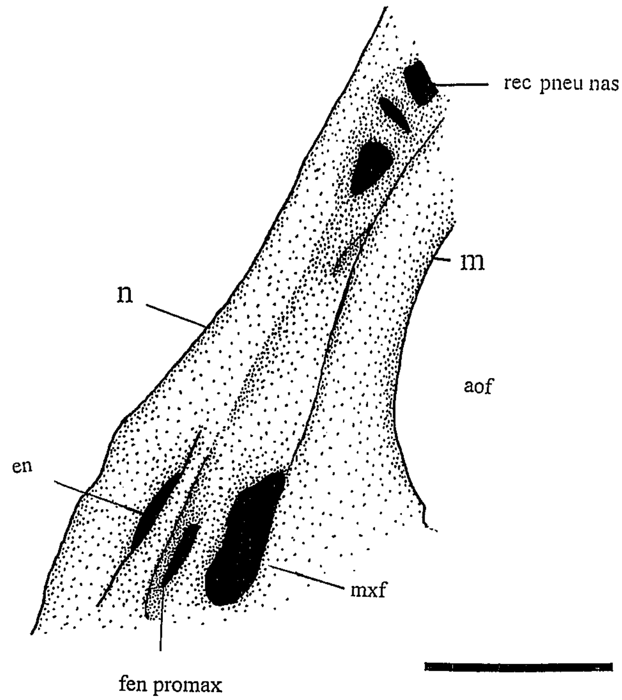


*Figure 4. Posterolateral view of maxilla showing fenestrae in the ascending process. Abbreviations: fen promax, promaxillary fenestra; pmf, promaxillary fenestra; rec pneu nas, nasal pneumatic recess (recessus pneumaticus nasalis); or as in Figure 2. Scale bar equals 10 cm.*

In BYU 2028, both the right and left dentaries have 18 teeth or alveoli, falling within the range of variation expected for *Allosaurus fragilis* (Madsen, 1976). On the left side, teeth 1–3, 7–11, and 15–18 are present. One, 2, 7, and 8 are broken at the tips. There is a short replacement tooth in the fourteenth alveolus. In the right dentary, 4–6, 8, and 10–14 are preserved. There is a replacement tooth in the seventeenth alveolus.

*Splenial.*—The right splenial (Figure 6) is thin and triangular, with an evaginated posterior end. It is similar to other specimens of *Allosaurus* (Madsen, 1976) and *Sinraptor* (Currie and Zhao, 1993). As in *Sinraptor*, the ventral margin thickens posteriorly. The anterior mylohyoid foramen is large in both mandibles, extending to the ventral edge of the splenial. The anterior end of the splenial bifurcates into two small processes, one above the other (Lisak, 1980). The higher one forms part of the ventral border to the supradentary. The lower process is longer than the first and lies in Meckel's groove.

The prearticular, coronoid, and surangular are fragmentary, so this specimen provides no new information on these bones.

## DISCUSSION

Individual and ontogenetic variation in the pneumatic system of the *Allosaurus* cranial region was described previously using braincases of different sizes from Cleveland-Lloyd Dinosaur Quarry, Utah (Chure and Madsen, 1996). BYU 2028 is now used to document some of the range of morphological and paranasal pneumatic variation present in the *Allosaurus* skull. Previous descriptions of *Allosaurus* (Madsen, 1976) and *Sinraptor* (Currie and Zhao, 1993) are used as a basis for comparison. Witmer (1997) provided a discussion and illustrations of the general paranasal pneumatic system of *Allosaurus*. BYU 2028 was compared with disarticulated *Allosaurus fragilis* material from Dry Mesa Dinosaur Quarry, Colorado, Dinosaur National Monument, and previous descriptions of this species (Madsen, 1976). The paranasal pneumatic system and the nasal crest are more extensively developed than observed in other specimens of *Allosaurus*. However, most of the bones are very similar to typical *Allosaurus* elements (Madsen, 1976; Currie and Zhao, 1993). On this basis, the present specimen is regarded as an adult specimen of *Allosaurus fragilis* with some unusual characters.

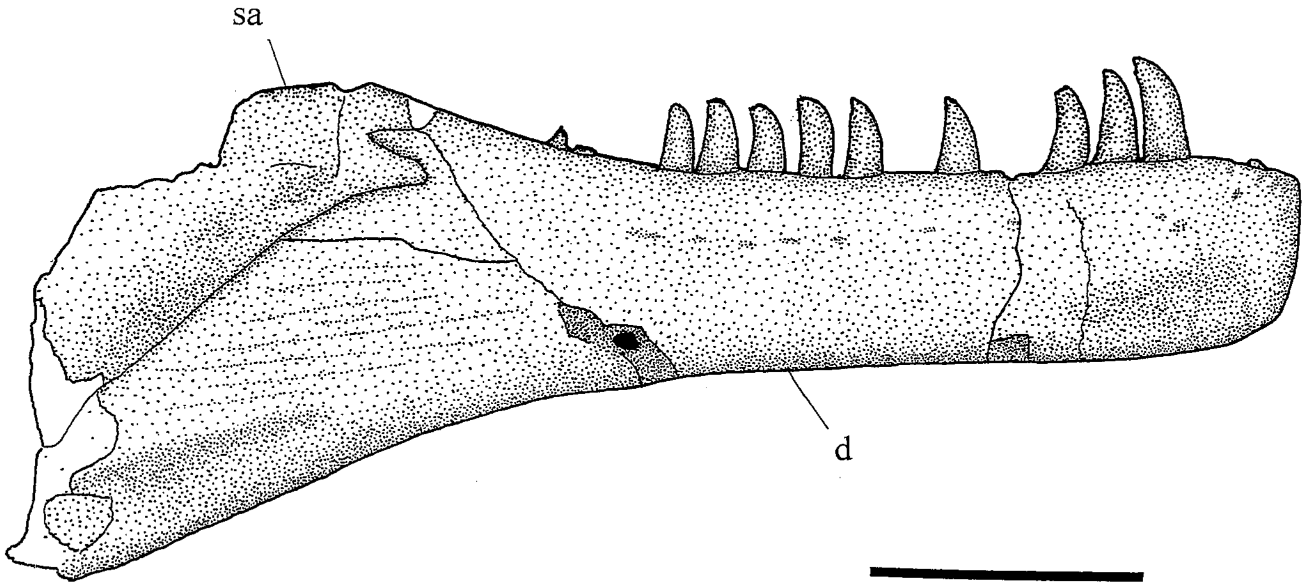


*Figure 5.* Allosaurus fragilis *right mandible (BYU 2028) in lateral view. Abbreviations: an, angular; d, dentary; sa, surangular. Scale bar equals 10 cm.*

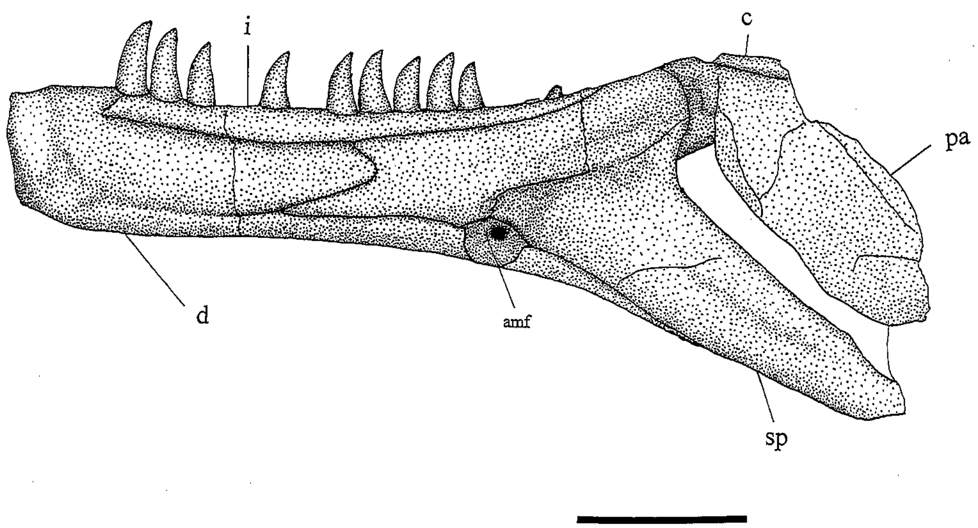


*Figure 6.* Allosaurus fragilis *right mandible (BYU 2028) in medial view. Abbreviations: amf, anterior mylohyoid foramen; c, coronoid; d, dentary; i, intercoronoid; pa, prearticular; sd, supradentary; sp, splenial. Scale bar equals 10 cm.*

This specimen of *Allosaurus* shows an increase in the amount of morphological and pneumatic variation seen within this taxon. The results reinforce the relative amount of variation in different parts of the *Allosaurus* skull. Morphological variation can include variation in the degree of development and ornamentation of crests on the skull. Witmer (1997) observed that the pattern of pneumatic development within the theropod clade generally increases over time, but that it is difficult to identify an orderly pattern in the development of accessory cavities. Additionally, development of paranasal pneumatic cavities can vary within a single theropod species. No other observed specimen of *Allosaurus fragilis* has such an enlarged pneumatic system in the nasal. However, the presence of pneumatic openings can vary from specimen to specimen and even from side to side as has previously been noted (Chure, pers. com. 1999). Variation of this type does not appear to be related to ontogeny. Therefore, the expanded cavities within BYU 2028 are associated with individual variation.

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