Rice University

Speleogenesis in Comal County, Texas

by

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Thesis Director's signature:

James Lee Wilson

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Caves in Comal County, Texas, were examined with regard to their lithologic and geomorphic setting, paying particular attention to controls such as stratigraphic variation, topography, jointing, and ground-water flow.

In the light of these data, a new classification of caves is proposed based upon the mode of water flow involved in their formation. Influent caves are formed by water flowing from the surface to the ground-water table. Effluent caves are formed by water flowing from the ground-water reservoir to the surface. Conduit caves are formed principally by phreatic flow with little, or no, surface relationship. This classification is extremely useful in identifying the factors involved in speleogenesis when used in conjunction with areal maps of the aforementioned controls.

Effluent caves in the lower Glen Rose Formation are localized within a massive, fossiliferous aquifer and oriented generally down-dip, thus substantiating Gardner's (1935) theory of speleogenesis.

Influent caves in both the upper and lower Glen Rose Formation are developed in areas with low surface gradient and consequently high infiltration. They develop vertically until the water reaches a suitable calcareous stratum which conducts it away laterally. A later change of conditions may cause further deepening and a series of pits and passages may develop. Conduit caves in the upper Glen Rose Formation appear to be localized within the more calcareous strata because of the high
solubility of these layers in contrast to the shales, marls, and
dolomites composing the major part of the section. Secondary col¬
lapse of the overlying less soluble strata may provide access for
additional inflow, but in most cases this can be eliminated as the
primary cause of cavern development. Vadose inflow and the mixing
effect which Thrailkill (1968) has postulated as causes of increased
solution do not seem responsible either. All the conduit caves ex¬
amined in detail, however, occur in areas of ground-water convergence.
It is hypothesized that the abnormally high flow rate and volume due
to this convergence is responsible for their development, thus
supporting the mechanism proposed by Swinnerton (1932) and Davies
(1957).

A cursory examination of caves in the Edwards Limestone reveals
that effluent caves may also be caused by the overflowing of a
perched aquifer into surface valleys. In the Edwards Limestone it
also appears that conduit caves may be localized in a horizon which
has high permeability, even within a compositionally homogeneous
section.
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INTRODUCTION

General Statement

Over the past thirty-eight years various theories have been advanced to explain the origin of limestone caverns. An ever increasing amount of evidence has been accumulated attempting to clarify the controversy over which theory is correct. More recently, speleologists have begun to feel that no single theory explains the origin of all caverns, but that different theories may be operating under different geologic and geomorphic conditions.

It is the purpose of this paper to report the results of an investigation in an area where caves are quite common (Comal County on the Edwards Plateau of Central Texas) and by studying the relationships of the various caves to their geologic and geomorphic settings to delineate which processes of speleogenesis are operating. In order to understand the various factors controlling speleogenesis, one must first be familiar with the various theories and their mechanisms. The first portion of this paper is devoted to a review of the major theories of speleogenesis and several minor mones which are here applicable.

In order to formulate a theory of origin for groups of caves, rather than individual caverns, a new classification of caves is proposed. Following the review, this classification is explained and its categories are defined.

The framework within which the caves are forming and which controls the mechanisms available for their formation is the
stratigraphy and geomorphology of the region. The second section of this paper is devoted to a review of the regional geology of Comal County.

Following these sections, the caves of Comal County (primarily those in the Glen Rose Formation) are examined in detail. They are grouped according to their stratigraphic occurrence and their position in the newly proposed genetic classification. Conclusions regarding the speleogenesis of each group are presented at the end of the pertinent section and, finally, all the conclusions are summarized.

Acknowledgments

Financial support for this study was provided by the Geology Department of Rice University. Field assistance was provided gratis by Gary Temple for the summer of 1967, Robert Olson for one week in the winter of 1967-68, and Explorer Scout Post # 43, Houston, Texas, on weekends throughout the study. Invaluable advice and assistance were provided by my advisor, Dr. James Lee Wilson, by other members of the Rice faculty, and by graduate student A. Richard Smith (University of Texas).

Thanks must also go to the ranchers and property-owners in Comal County who were extremely courteous and helpful in allowing me to work on their property. Particular mention must be given to Mr. and Mrs. Harry Heidemann, the owners of Natural Bridge Caverns, who allowed me to make repeated trips into their cave and provided me with maps and other valuable data.

Finally, thanks are due to my wife, Patricia Beck, who not only
typed the final copy of this thesis, but also endured my frequent
absences and repeatedly washed clothes heavily laden with red clay and
bat guano.
Theories of Speleogenesis

Speleogenesis, the study of the origin of caves, is a young and still controversial subject. The two alternative theories which currently vie for scientific validation were first formulated by Davis (1930) and Swinnerton (1932). In the decade following these two papers several other theories were advanced (see below), but in the late 1940's and early 1950's several comprehensive field studies invalidated most of the alternative theories. Current controversy exists, principally between modifications of the two earliest papers. In the following paragraphs I will examine the two major theories of cave formation and the types of evidence which may be cited to reinforce each. I will also mention several of the lesser known approaches, particularly one by Gardner which is ideally exemplified in one area of Comal County, Texas.

In 1930, William Morris Davis, who is principally known for his work in geomorphology, published the first thorough and detailed study of caves in the United States. Former theories assumed that caves were excavated and enlarged by processes similar to those working upon surface stream valleys, that is, abrasion by moving water and its sedimentary load (Davis, 1930, p. 477-480). Davis reasoned that, if this was correct, then caves should also exhibit the other processes and forms developed in surface valleys. However, upon examination of a large number of crude cave maps (the only type of evidence available at the time), Davis found many facets of caves
which contrasted with surface valley development. Principle among these were passages in closed loops, of which maze caves are the epitome; passages branching in a downstream direction; a lack of dendritic ground-plan; and the vertical irregularities of many caves which could not be formed by a stream eroding to grade (Davis, 1930, p. 497-548).

Having thus invalidated most of the then-current ideas, Davis reexamined his data and promulgated his own theory of speleogenesis based upon solution by underground water, not abrasion. Bretz (1942) later modified this theory by adding an additional step, but the essential idea of cave formation was not altered. The following is a summary of the Bretz-Davis theory as paraphrased by White (1959, p. 2-30):

"1. Most caves are made by a phreatic circulation of meteoric water beneath the mature topography which preceded the present erosion cycle.

2. During old age, cave-making ceased as the hydrostatic head disappeared with reduction of the uplands. To a large extent the existing caves then became filled with residual red clay filtered down from the peneplain soil. Remnants of this clay fill are considered a valid record of peneplanation.

3. Later uplift caused deep dissection of the peneplain surface. This lowered the water
table and brought most of the caves into the vadose zone.

4. Removing the clay fill, the ensuing vadose circulation is devoted more to restoring the original phreatic caves than it is to enlarging them."

Two principle points to be remembered from this theory are, first, that the formation takes place deep within the phreatic zone where circulation is extremely slow, and second, that the caves are formed under the preceding erosion cycle and, therefore, have very little relation to the present surface topography.

A.C. Swinnerton (1932), working with much the same type of evidence as Davis, arrived at a different set of conclusions. Swinnerton thought that the velocity of the water circulation was an important factor. He postulated that rapidly moving ground-water, even though it could not reach saturation, would more effectively dissolve limestone than slowly moving ground-water which could become saturated. Thus, the deep phreatic zone was impotent for the solution of large caves and another zone of more rapid flow needed to be identified.

Swinnerton (1932) hypothesized that the flow should be greatest along the path of least resistance. Because wall friction along the joints is the only important form of resistance, the most active flow path should be the shortest one, that is, directly along the water table to the local base level. Swinnerton emphasized short-term
fluctuations due to flooding which would increase the hydrostatic head and thus the flow rate. Because the water flowed along the water table, Swinnerton called his theory the water table theory.

Davies (1957) modified this theory slightly, deemphasizing the effect of flooding and localizing the flow directly below the water table (the shallow phreatic zone). Flow in this zone would be particularly effective in dissolving limestone over long periods when the water table was stable. The following outline is Davies' modification of Swinnerton's water table theory (White, 1959, p. 2-32).

1. The development by solution of primitive openings along joints, cleavages, fractures, bedding planes, and intermolecular spaces at random depths within the phreatic zone.

2. Mature enlargement and integration of primitive openings into cavern passages by slowly moving subwater-table streams directly beneath the water table during a period of stability related to terrace development. The water table near major drainageways under such conditions will be uniform, stable, and nearly horizontal allowing the development of horizontal passages with a rectangular cross section regardless of rock structure and stratigraphy. This is in
part the idea expressed by Swinnerton when he proposed cavern development in the zone of 'lateral flow' directly beneath the water table.

3. The filling of mature cavern passages with clay, sand, and gravel under alternating vadose and phreatic conditions.

4. Excavation of cavern fills by vadose streams. Development of stalactites, Flowstone, and similar speleothems under vadose conditions."

Many recent investigations (Sweeting, 1950; Davies, 1960) have attempted to correlate cavern levels and terraces, but the evidence is not yet definitive enough to say that this theory is corroborated.

Thrailkill (1968) lent support to the shallow phreatic theory of Swinnerton and Davies, but for drastically different reasons. Thrailkill agrees that speleogenesis is localized by the water table, but does not believe that current velocity is responsible for this. Using a theoretical treatment of ground-water flow in a limestone reservoir which contains primitive solution channels, he shows that the shallow and deep phreatic velocities should be virtually identical. He examines other factors which might localize solution in the shallow phreatic zone and, of these, vadose inflow and mixing appear to be most prominent. That is, due to the convex nature of the calcium carbonate solubility curve (with respect to carbon dioxide
partial pressure) the mixing of a saturated solution at one carbon dioxide partial pressure and a saturated solution at a different partial pressure may yield a mixture which is un-saturated (Thrailkill, 1968, Fig. 9). Thus, the mixing of saturated vadose water and saturated phreatic water may cause un-saturation, if their carbon dioxide pressures differ, giving the area of mixing added solution power. This geochemical approach is new and supporting evidence has not yet been gathered. Despite Thrailkill's new ideas, however, certain factors in the study of speleogenesis in Comal County seem to indicate that flow velocity is indeed important.

In addition to the two primary theories of speleogenesis, a number of lesser known theories have been advanced. Piper (1932) proposed a theory based upon solution in the vadose zone. Most authors since have found Davis' original objections strong enough to invalidate this theory. Malott (1937) formulated another theory based principally on the action of "sinking streams" upon joints which had been partially enlarged in the phreatic zone. Bretz (1942) demonstrated that stream action was, in most cases, secondary and simply modified a preexisting cavern.

Gardner (1935) proposed a theory based upon the tapping of artesian aquifers by down-cutting surface valleys (see figure 23a). According to Gardner, large caves will form on the up-dip side of major valleys as the artesian pressure causes the water to flow from the surface, down the dip of the aquifer, and into the valley. White (1959,p. 2-14) says "Gardner's paper is a masterpiece of weighty
conclusions from very skimpy data. He has investigated in the field only a few of the caves of the Kentucky big cave country. How he determined that the caves always formed on the up-dip side of the valley, elongated along the dip in a day when a good cave map did not exist is something of a mystery. It should be pointed out that caves are not generally dip caves. Secondly, lithology is of rather minor importance. Caves in the Greenbriar Limestone have been known to cut the entire thickness of beds which range from pure limestone to limey shales." In contrast, I will present evidence later which, I believe, demonstrates effectively that this theory is responsible for the origin of some caves.

Classification of Caves

In order to deal more effectively with the origin of caves in Comal County, Texas, a general genetic classification of caves is proposed. Caves may be subdivided into three categories, based upon the type of water flow involved in their origin: influent caves, which are primarily vertical and are formed by water flowing from the surface to the water table (sinkholes and modified sinkholes); effluent caves, which are normally horizontal and are formed by water flowing from the ground-water reservoir to the surface (spring associated caves); and conduit caves, which are formed by water flowing along the surface of the water table and have no surficial opening except by secondary modification.

These genetic definitions need not necessarily hold at the present, for a lowering of the water table may have robbed the caves of their
original function, but from geomorphic and hydrologic evidence it is usually possible to classify caves in Comal County into one of these categories. It may also be possible to find caves, or cave systems, which may combine two of these categories. For instance, a sinking river could first be influent, and later, at its resurgence to the surface, be effluent.

The subdivision of caves into these categories allows one to analyze more effectively their origin with respect to the surface geomorphology, drainage, and lithology. A location map of all the caves in Comal County reveals very little, even when the geology, topography, and ground-water levels are superimposed. However, a location map of all effluent caves clarifies their role in the geomorphic cycle and the influence of geology on their development. This yields valuable hypotheses upon which one may base his field investigations.

In summary, then, the primary purpose of this investigation is to examine the caves of Comal County, Texas, particularly those in the Glen Rose Formation, and to glean from this investigation pertinent facts which may further substantiate (or invalidate) one, the other, or several of the proposed theories of speleogenesis.
Comal County is located approximately thirty miles northeast of San Antonio and sixty miles southwest of Austin in Central Texas. It lies primarily within the Edwards Plateau physiographic province, although a small portion of the county, on the southeastern edge, is in the Gulf Coastal Plain. The boundary of these two provinces is marked by the Balcones Fault Zone which, in the immediate area, trends to the northeast. The effect of the Balcones faulting has been to divide the bedrock of the county into a number of parallel blocks, usually downdropped to the southeast (George, 1952).

The Edwards Plateau to the northwest of the fault zone consists primarily of outcropping Edwards Limestone. However, in the Comal County area the plateau has been more thoroughly dissected and eroded so that the Edwards here occupies only the higher portions of the terrain. Exposures of the Glen Rose Formation cover approximately two thirds of Comal County, the lower member to the west and the upper member in the central portion (see figure 1). Formations above and below the Edwards and Glen Rose cover only a small portion of the county, but may play significant roles in the ground-water cycle.

The complete section of the Cretaceous rocks in central Texas is presented in Table I, and a reference section of the Trinity Division, which includes the Glen Rose Formation, is presented in figure 2. The contact between the Cow Creek Limestone and the Hensell Sand (members of the Travis Peak Formation) is indicated to be
Figure: 1
Geologic Map of Comal County, Texas
From: Rhoades and Guyton, 1955.

EXPLANATION

FORMATIONS YOUNGER THAN FREDERICKSBURG GROUP

FREDERICKSBURG GROUP

GLEN ROSE LIMESTONE

TRAVIS PEAK FORMATION

CONTACT, DASHED WHERE APPROXIMATELY LOCATED

FAULT, DASHED WHERE APPROXIMATELY LOCATED

AREA COVERED BY DETAIL ON MAP, FIGURE 1

GENERAL AREA IN WHICH GEOLOGIC SECTION WAS MEASURED

WELL USED IN CROSS SECTION

DATE OF MEASUREMENT

ELEVATION OF STATIC WATER LEVEL

ELEVATION OF INTERVAL TESTED

AREA COVERED BY RESERVOIR AT APPROXIMATE ELEVATION OF CONSERVATION POOL, 948 FEET
TABLE 1: THE CRETACEOUS SYSTEM IN CENTRAL TEXAS

<table>
<thead>
<tr>
<th>SERIES</th>
<th>GROUP</th>
<th>FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Eagle Ford Shale</td>
</tr>
<tr>
<td></td>
<td>Disconformity</td>
<td>Buda Limestone</td>
</tr>
<tr>
<td></td>
<td>Comanche</td>
<td>Grayson Shale (Del Rio)</td>
</tr>
<tr>
<td></td>
<td>Washita</td>
<td>Georgetown Limestone</td>
</tr>
<tr>
<td></td>
<td>Disconformity</td>
<td>Edwards Limestone</td>
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<tr>
<td></td>
<td>Fredericksburg</td>
<td>Comanche Peak Limestone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Walnut Clay</td>
</tr>
<tr>
<td>Trinity</td>
<td></td>
<td>Glen Rose Formation: Upper Member</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Member</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Travis Peak Formation: Hensell Sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cow Creek Limestone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pine Island Shale</td>
</tr>
<tr>
<td></td>
<td>Sligo Formation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hosston Formation</td>
<td></td>
</tr>
</tbody>
</table>

From: Rhoades and Guyton, 1955
Fredricksburg Division (app. 400')

Upper Glen Rose Limestone

Corbula Bed

Lower Glen Rose Limestone

Hensel Sand

Cow Creek Limestone

Hammett Shale

Sycamore Sand

Paleozoic

Figure 2: Trinity Reference Section
Modified from: Lozo and Stricklin, 1956
unconformable on the reference section, but both George (1952) and Rhoades and Guyton (1955) present no evidence to indicate this unconformity within Comal County.

The Cow Creek Limestone Member of the Travis Peak Formation is the oldest unit cropping out in Comal County. It occupies only a limited area along the Guadalupe River and Rebecca Creek and is approximately eighty feet thick. The upper forty feet is grey, fossiliferous limestone and dolomite while the lower forty feet is more argillaceous and shaly (George, 1952). A good exposure of the upper Cow Creek Limestone occurs in the canyon of the Guadalupe River just west of Scheppes Crossing.*

The Hensell Sand Member of the Travis Peak Formation overlies the Cow Creek Limestone and, as previously mentioned, doubt exists as to the nature of the contact. This portion of the section does not relate directly to cavern formation in Comal County and the problem was not further investigated. The Hensell Sand is light tan, sandy, and slightly dolomitic. Variations between the individual beds of the member range from dolomitic sandstone to slightly sandy marl. The upper layers, where I have seen them in the field, are slightly dolomitic sandstones (less than ten percent dolomite). The Hensell-Glen Rose contact will be discussed in more detail below because it bears directly on the formation of several of the larger caves in Comal County.

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*Scheppes Crossing is the low water crossing of the road from Bulverde to Spring Branch over the Guadalupe River. The road has no route number.
Conformably overlying the Travis Peak Formation is the Glen Rose Formation. The Glen Rose Formation is subdivided into an upper and a lower member using a thin marker bed, composed predominately of fossils of *Corbula martinea*, as the boundary (Lozo and Stricklin, 1956). The lower Glen Rose is composed largely of massive, fossiliferous limestones with occasional rudist reef mounds and some thin shaly beds. In Comal County the lowest thirty feet of the Glen Rose is massive, scarp-forming, organic limestone composed of foraminifera, oysters, clams, and pellets in a micritic matrix.

In contrast, the upper Glen Rose Formation consists of a series of alternating limestones, marls, and occasional dolomites, with evaporite beds present west of Comal County. When exposed it weathers with characteristic relief to yield a readily identifiable stair-step topography. Hydrologically, it also differs from the lower member because the frequent marl beds decrease its vertical permeability. In contrast, the massive limestones of the lower member form good aquifers.

Conformably overlying the Glen Rose Limestone is the Walnut Clay, which to the north is subdivided into four to six members, totaling approximately one hundred-fifty feet. In Comal County, however, the Walnut Clay is a sandy marl with occasional calcareous nodules totaling less than five feet. An excellent exposure is present on the road-cut ascending Devil's Backbone on Route 32.

The Comanche Peak Limestone overlies the Walnut Clay, and there is some controversy as to its existence in Comal County.
George (1952) places its thickness at twenty to fifty-five feet; however, the cross-section of Moore (1964, p. 22) shows no Comanche Peak in Comal County or in Hays County, to the northeast. Hydrologically, the Comanche Peak Limestone is not distinguished from the overlying Edwards Limestone because their permeabilities are relatively similar (George, 1952).

The Edwards Limestone lies conformably above the Comanche Peak Limestone and is predominantly hard, massive limestones with occasional shale lenses. Most of the Edwards Limestone is honeycombed and consequently highly porous, yielding water to many large wells and springs in this area. A characteristic of the Edwards Limestone is large chert nodules which occur in the upper portion of this formation and in no other Cretaceous strata in Comal County.

The formations overlying the Edwards Limestone belong to the Washita Group and are, in ascending order, the Georgetown Limestone, the Grayson (Del Rio) shale, and the Buda Limestone, totaling approximately 150 feet (George, 1952). Their outcrop distribution and lithology bear little relationship to this study since no major caves are formed in them. However, the contact between the Edwards and the Georgetown Limestone is disconformable (George, 1952) and the subaerial solution and erosion of the Edwards Limestone which took place prior to the deposition of the Georgetown Limestone appears to play an important role in the localization of caves in the older formation.

Above the Washita Group is the Gulf Series consisting of the
Eagle Ford Shale, the Austin Chalk and the Taylor Marl, totaling approximately 500 feet (George, 1952). Again, none of these formations contain significant caves in this area. Overlying the Gulf Series are Pliocene and Pleistocene gravels and Recent alluvium.

All of the Cretaceous strata are cut by faults associated with the Balcones zone and, in addition, are extensively jointed. In Comal County seven major faults are detectable, trending between N. 45° E. and N. 60° E. (George, 1952). In addition many minor faults have also been mapped. Three sets of major joints have been detected and trend N. 20-30° E., S. 55-70° E., and E.-W. (Boyer, 1957). However, jointing is highly developed and minor trends may be detected in several additional directions.

Lithology is one of the variables which controls the formation of caves. Knowledge of the detailed section of the Glen Rose Formation in Comal County is due, almost entirely, to Rhoades and Guyton (1955) in their study of the Canyon Dam site. No detailed study of the Fredricksburg Group (the Paluxy Sandstone, Walnut Clay, Comanche Peak Limestone and Edwards Limestone) has been published for Comal County. For this reason, most of the detailed analysis of cavern formation must be confined to the Glen Rose Formation and only generalities can be made concerning the caves in the Edwards.
CAVERN DEVELOPMENT IN THE LOWER GLEN ROSE FORMATION

Effluent Caves

There are four caves formed in the lower Glen Rose Formation which are effluent. The location of three of these (Bartel's Cave, Jordan's Cave, and Honey Creek Water Cave) and the local geology are shown on figure 3; the fourth cave, Wolle Cave, is located approximately ten miles east of the others and will be discussed later. Of the four, all but Jordan's Cave have been mapped (figures 4, 5, and 6). Two of these effluent caves, Bartel's Cave (formerly Bender's Cave) and Honey Creek Water Cave, were visited and examined. Wolle Cave is now covered by Canyon Lake; Jordan's Cave (formerly H. C. Plumly Cave) was issuing water at several thousand gallons per minute when visited and, due to the current, was impassable. However, data are available for both the later caves (Reddell, 1964).

Bartel's Cave and Honey Creek Water Cave are physically similar. Both are long, horizontal caves partially filled with water. Both caves open onto the scarps of small creek valleys and both have secondary springs developed below their main entrances. In both cases the cavern-spring system is a perennial source of water, and both caves have similar ceiling development, arched with domes occurring commonly.

Jordan's Cave and Wolle Cave are also long, horizontal, and partially filled with water. Both open onto the side of a stream valley, Jordan's Cave feeding Spring Branch Creek and Wolle Cave draining into the Guadalupe River. More detailed data than this has not been published (Reddell, 1964).

In addition, the occurrence of three of the caves around the
Figure 3: Location of Three Effluent Caves

A1 Bartel's Cave
A2 Jordan's Cave
A3 Honey Creek Water Cave

\[\text{Base map: George, W.O., 1952.}\]
Figure 4:
WOLLE'S CAVE
Comal Co., Texas

Brunton & Tape Survey
by UTSS, 3-63


Continues low
approx. 500 ft.

Travertine Dams

ENTRANCE PROFILE
Figure 5:
HONEY CREEK WATER CAVE
Comal Co., Texas
Brunton & Tape Survey
by UTSS, 2-11-63

periphery of the Travis Peak outcrop area indicates that they may be developed in similar lithologies. Table II is a summary of chemical and thin-section analyses of samples taken near the mouths of Jordan's, Bartel's, and Honey Creek Water Cave. Samples B-F were collected from a measured section at Jordan's Cave, B being lowest; samples H and G are from the scarp and overlying bed, respectively, at Bartel's Cave; sample I is from the scarp at Honey Creek Water Cave.

From the measured section at Jordan's Cave it is apparent that beds B-D are the upper strata of the Hensel Sand and bed E is the lowermost Glen Rose Formation. Bed C is developed into a honeycombed solution structure, bed D appears resistant, and bed E shows high porosity due to the solution of many large fossils. Jordan's Cave is developed in beds C, D, and the lower few feet of bed E. However, the scarps at both Bartel's Cave and Honey Creek Water Cave were identical to bed E, both in gross physical appearance and thin-section analysis, and, further, were very similar in MgO/CaO ratios. Both the latter caves are developed totally within bed E.

From its composition and stratigraphic position, it is apparent that bed E is the lowermost, massive, "reef" zone of the Glen Rose Formation which Rhoades and Guyton (1955) have identified as a major artesian aquifer. However, I believe that the thickness of fifty feet (Rhoades and Guyton, 1955) is slightly overestimated; in all areas in which I have measured this section the massive portion is twenty-five to thirty feet thick and capped by a compact, non-porous, highly resistant biomicrite (bed F and bed G). The surficial
Table 2: Analysis of samples collected near effluent caves

<table>
<thead>
<tr>
<th>Sample</th>
<th>F</th>
<th>G</th>
<th>D</th>
<th>O</th>
<th>B</th>
<th>E</th>
<th>G</th>
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<tr>
<td>Thickness of bed sampled (inches)</td>
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<td>25</td>
<td>1/6</td>
<td>15-20</td>
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<td>Brittletober %</td>
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<td>30</td>
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*Versene titration following Jodry, 1955.*
weathering characteristics of this overlying bed are evidence that it would form an effective cap for an artesian aquifer.

Wolle Cave is located five feet above the Guadalupe River approximately two miles south of Demijohn Bend (Reddell, 1964). From the topographic map its elevation is approximately eight hundred-fifty feet, which is the same as the elevation of the aforementioned aquifer at that locality (Rhoades and Guyton, 1955). It is apparent, then, that all four effluent caves in the lower Glen Rose Formation are developed in the same bed, which is a major artesian aquifer.

The dip of the strata in this area is approximately ten feet per mile to the east or southeast, although it varies locally. Honey Creek Water Cave trends northeast, while both Bartel's Cave and Wolle Cave trend almost due east. Detailed information is not available, but it appears that Jordan's Cave trends to the south or southeast. With this latter exception, these caves are trending generally down-dip, and draining in that direction. However, Bartel's Cave and Jordan's Cave are located such that Bartel's Cave would receive most of the water from the west and Jordan's Cave would only receive drainage from the north and northwest (see figure 3). With this modification, Jordan's Cave is draining down-dip as much as local hydrologic conditions will allow.

In summary, the effluent caves in the lower Glen Rose Limestone are developed in a massive artesian aquifer, elongated generally down-dip so as to drain the aquifer into present surface valleys.
These caves exemplify the conditions outlined by Gardner (1935) and there can be little doubt that Gardner's theory of speleogenesis is applicable to these caves.

**Influent Caves**

There are a large number of influent caves in the lower Glen Rose Formation in Comal County. Most of these are shallow sinkholes, known only to the owner of the property on which they occur. Only the largest of the twenty-seven influent caves listed by Reddell (1964) were examined for this study.

Three of these twenty-seven caves occur on the Dierk Ranch and are actually in Kendall County (personal communication from the ranch owner). Most of the remaining twenty-four caves occur in two geographic regions: three in the west central portion of the county near Honey Creek, and nineteen in the southwest corner of the county near Cibolo Creek. The remaining two are relatively isolated.

The location of Honey Creek Water Cave (effluent) and the three influent caves near it is shown on figure 7. Pot Hole and Pot Hole Pit are shallow sinkholes, approximately fifteen feet deep; Honey Creek Dry Cave is a larger sink with a break-down floored room, twenty feet in diameter, at its base.

Honey Creek Water Cave is primarily developed along one linear trend, approximately N. 43° E. (see figure 5). It is probable that this linearity is controlled by a joint developed parallel to the major faults in this area. A straight line may be drawn approximately through all three influent caves and through Honey Creek Water Cave.
Figure 7: Location of Influent Caves Near Honey Creek

1. Honey Creek Water Cave (effluent)
2. Pot Hole
3. Pot Hole Pit
4. Honey Creek Dry Cave

0 1 2 Miles

Base map: George, W.O., 1952.
(figure 7). The bearing of this line is also N. 43° E. Thus, these three caves, or sinkholes, are simply "feeders" to the effluent cave and are developed along the same joint which controls it.

The location of the nineteen caves in the other group and the local topography are shown on figure 8. The area within the dashed circle contains fifteen of these, of which Klar's Cave is of major importance. The other four caves are Schaeffer Cave, Schaeffer Pit, Calmbach Cave, and Walter Grosser Cave (incorrectly called Wortheim Cave by Reddell, 1964).

Figure 9 is a map of Klar's Cave; figure 10 is a sketched profile of Calmbach Cave. Klar's Cave is a highly modified sinkhole, with extensive lateral development connecting the various vertical segments. Calmbach Cave is also a modified sinkhole, progressing downward in a series of ten to fifteen foot drops for a total vertical extent of approximately eighty feet. Schaeffer Cave consists of a twenty-five foot deep sinkhole with a three hundred foot passage, two to five feet high, at the base. Walter Grosser Cave is an unmodified vertical sink thirty-one feet deep, and Schaeffer Pit is an unmodified sinkhole approximately seventy feet deep.

The topography of this area along Cibolo Creek is distinctly different from that of the remainder of the Glen Rose outcrop in Comal County. Whereas most of the Glen Rose topography is hilly, with stair-step slopes (due to the alternating limestones and marls) and sharp divides, this area is one of broad, gently sloping fields. All of the influent caves are confined to these broad lowlands (figure 8). High infiltration due to these abnormally low surface gradients is
Figure 8: Location of Influent Caves in the lower Glen Rose Limestone

1 Klar's Cave
2 Schaeffer Cave (approx. location)
3 Schaeffer Pit (approx. location)
4 Calmbach Cave
5 Walter Grosser Cave

Area of many shallow sinkholes and caves

0 1/2 1
Miles

(U.S.G.S. topographic base map. Bergheim, Texas, 1964.)
the controlling factor in the areal distribution of these influent caves.

In addition to this topographic control, are there also factors controlling the vertical extent of these caves? That is, is any one stratigraphic zone (for instance, a particular aquifer) particularly favorable for cavern development? Figure 11 shows the vertical distribution of these five caves set in the local stratigraphic cross section (after Rhoades and Guyton, 1955). The elevations of the cave entrances were determined using a Wallace & Tiernan altimeter and correcting for barometric fluctuations by frequently measuring sites of known altitude. The accuracy is estimated at better than ± 5 feet. The dip of the strata was corrected from that of the original section (Rhoades and Guyton, 1955, figure 8) to a value of 7.5 feet per mile (approximately along the line of section). The corrected dip was determined with an alidade over a distance of 2,450 feet.

From figure 11 it is evident that the caves do not end at any one stratigraphic horizon. In addition, they terminate too far below the upper aquifer and too far above the lower aquifer to be related to either. In fact, the only generality which can be made is that all but one of the influent caves terminate in limestones rather than marls.

Because three of these caves penetrate the upper aquifer and are not water filled (except in time of flooding) it appears that this aquifer is not functioning in this immediate area. This hypothesis is further reaffirmed by the fact that Cibolo Creek, which carries water only in periods of flooding, is below the aquifer, and, that the
Figure 11: Influent Caves in the Lower Glen Rose Formation

1  Klar's Cave  3  Schaeffer Pit
2  Walter Grosser Cave  4  Schaeffer Cave
5  Calmbach Cave (approx)

Note: Blank areas are covered and are usually marls or shales.
Section from: Rhoades and Guyton, 1955.
one decoded well (George, 1955, p. 98, well D-13) that penetrates this aquifer has a water level below it. However, because Calmbach Cave has actively flowing water at its bottom, the limestone layer there must be an aquifer (probably minor when compared to those identified by Rhoades and Guyton, 1955).

The fact that most of these influent caves terminate in limestone indicates that these layers were formerly artesian aquifers, presumably during a period of higher precipitation. The permeability of some may have been low, compared to the more massive, fossiliferous limestone layers, but it would certainly have exceeded that of the marls. In addition, the caves presently fill in times of flooding and drain rapidly thereafter; this indicates that these layers may still occasionally function as aquifers. It appears, then, that these influent caves are controlled vertically by the presence of minor aquifers which act to conduct the water laterally and thus halt further vertical deepening of the caves.

Later changes, such as a lowering of the water table or the piracy of the water flow by another vertical joint, may cause further deepening. Thus, the complicated profiles of caves such as Calmbach's or Klar's may result.

The two remaining influent caves, Heimer Cave and Spring Branch Cave (figure 12) were not examined, but from their location and the published descriptions (Reddell, 1964) some hypotheses may be made as to their origin. Heimer Cave appears to be developed very near Swine Creek which is surrounded by an area of gentle slope and appears to flow along a fault. This cave is probably on a surface of low gradient.
Figure 12a: Location of Heimer Cave

Heimer Cave

\[ \text{Miles} \]


Figure 12b: Location of Spring Branch Cave

Spring Branch Cave

\[ \text{Miles} \]

(location: Reddell, J.R. (ed.), 1964; U.S.G.S. topographic base map, Spring Branch, Texas, 1964.)
and, like the caves in southwestern Comal County, is controlled by the increased infiltration available here and not in the surrounding hilly terrain. It is also very near the area where the massive reef aquifer of the lower Glen Rose Formation should outcrop and it probably conducts water along the fault to it.

Spring Branch Cave is very near Jordan's Cave and is developed along a fissure with water at the bottom (Reddell, 1964). The bearing from Jordan's Cave to Spring Branch Cave is approximately N. 55° W. (using locations from Reddell, 1964) which is also the bearing of one of the major joint trends (Boyer, 1967). Again, it is probable that this cave conducts water downward, along a joint, to the massive reef aquifer and from there to Spring Branch Creek or Jordan's Cave.

In summary, the influent caves of the lower Glen Rose Formation are controlled areally by topography with a low surface gradient or by major joints or faults where infiltration is high. They terminate in various limestone layers which are, or at one time were, aquifers, thus halting the vertical deepening of the caves by conducting the water laterally away.

Conduit Caves

So far as I can determine from my field studies and published descriptions (Reddell, 1964), there are no caves of the conduit type in the lower Glen Rose Formation in Comal County.
CAVERN DEVELOPMENT IN THE UPPER GLEN ROSE FORMATION

Effluent Caves

Assuming that effluent caves form by a process closely akin to Gardner's (1935) theory of speleogenesis, the existence of a major artesian aquifer (or possibly a perched aquifer; see figure 23b) becomes a prerequisite for their formation. Rhoades and Guyton (1955, p. 11) have recognized the presence of one artesian aquifer in the upper Glen Rose of Comal County, but its thickness is on the order of ten feet. According to their description, this aquifer "exhibits honeycomb characteristics when exposed at the surface," and it is likely that it contains minor caves under proper topographic conditions. However, no major caves have been discovered which can be correlated with it, which is probably due to its minimal thickness and consequent low flow.

Influent Caves

There are five influent caves in the upper Glen Rose Formation in Comal County. Four of these are grouped in the low gradient area along Cibolo Creek, and the remaining one is located in the northern part of the county near Fischer. The Fischer Cave, however, was not examined due to its extreme vertical drop (125 feet) and reports that it contains "bad air" (Reddell, 1964).

The approximate location of the four caves near Cibolo Creek is shown on figure 13. Their exact locations were not established due to their remote location accessible only by faintly discernable pasture roads. From field examination, however, it was determined that they are confined to areas of very subdued topography and low relief. The
Figure 13: Location of Influent Caves in the Upper Glen Rose Limestone

- Ebert's Cave
- Approximate location of Kappelman Cave, Kappelman Trash Cave, and Kappelman Salamander Cave.

dashed circle on figure 13 encloses three caves on the Kappelman Ranch (recently sold). Of these, Kappelman Cave was visited. The fourth cave is Ebert's Cave, located about one and a half miles to the east of the other three.

Ebert's Cave was mapped and Kappelman Cave sketched (figure 14) and their vertical extent was plotted on the local stratigraphic section (figure 15). From the section and their location, it is apparent that these influent caves in the upper Glen Rose Formation are similar in origin to those near Cibolo Creek in the lower Glen Rose. That is, they are formed in areas of low surface gradient due to increased infiltration. They terminate in a limestone, rather than a marl, the more porous limestone conducting the influent water laterally and thus halting further deepening of the caves.

**Conduit Caves**

Because it is composed of a series of alternating thin-bedded limestones, marls, shales, and dolomites, the upper Glen Rose Formation is generally presumed to be a poor cave-former. However, the two largest caves in the county, Natural Bridge Caverns and Bracken Bat Cave, and the smaller Dinosaur Cave are developed in this member.

Thrailkill (1968) concludes that the shallow phreatic zone localizes cavern formation, but that this is not due to high flow velocity. The localization is due, instead, to undersaturation caused by vadose inflow or backflooding (see discussion under Theories of Speleogenesis). In dealing with the three conduit caves in Comal County, and particularly with Natural Bridge Caverns, one cannot speak in terms of a shallow and deep phreatic zone because the hydrology is primarily artesian.
Figure 14a: Ebert's Cave
Comal Co., Texas

Figure 14b: Kappelman Cave
Comal Co., Texas
Figure 15:
Relationship of Influent Caves in the upper Glen Rose Formation to Lithology

Test Well T-1 from: Rhoades and Guyton, 1955.
However, before the development of the secondary porosity which now confines the major ground-water flow to the limestone beds, the flow was probably along a three dimensional network of joints, highly developed in this area due to its propinquity to the Balcones Fault Zone. I will show that these caves are developed in areas of unusually high flow and where the effects of vadose inflow or backflooding are probably not applicable. The data neither support nor contradict either theory definitely, but it does seem to stress the importance of high flow rates as Swinnerton's (1932) theory predicts.

Natural Bridge Caverns (figure 16) is one of the largest and most attractive caves in Texas, and a brief account of its history and some description follow. The sinkhole and entrance room of Natural Bridge Caverns have long been known to local residents, but not until a party of spelunkers from St. Mary's University began serious exploration in 1960 was the true extent of the caverns realized. From 1960 until 1963 exploration, mapping, and photography continued, and on March 7, 1963, the cave was opened to the public by its owners, Mr. and Mrs. Harry Heidemann and Reggie Wuest. A visitor's center now stands alongside the entrance pit and a shaft has been excavated from the Hall of the Mountain Kings to the surface so that tourists may exit there and ride back to the center.

Speleothems throughout the cave vary from tiny helictites and soda-straws to the massive stalactites, stalagmites, and columns of the Castles of the White Giants. In Boxwork Canyon, which unfortunately is not on the public route, the best developed boxwork in Texas
Figure 16a:
Map and Profile of Natural Bridge Caverns, North portion
Comal Co., Texas

Mapped by Alamo and University of Texas Grottos, 1963.

0 100 200 300 400 500
Feet


Figure 16b:
Map of Natural Bridge Caverns, South portion
Comal Co., Texas

Personal communication from:
O. Knox Jr., 1968.
is found and throughout the cave over one hundred-fifty "fried eggs"* may be seen. Glass doors now seal off both ends of the main cavern so that the humidity is not lost and almost all the speleothems are actively growing.

From the profile (figure 16) it is evident why Natural Bridge Caverns is classed as a conduit cave: first, the entrance descent is several times smaller than the main passages; second, the main passages extend both upstream and downstream (speaking of ground-water flow) from the entrance; and third, the prominent surface expression of the entrance area is primarily due to collapse, meaning that the original must have been much smaller or even non-existent. From these observations it is unlikely that the cave was formed by water flowing through the present entrance.

Figure 17 shows the location of both Natural Bridge Caverns and nearby Bracken Bat Cave on a topographic base. The bridge spanning the entrance sink of Natural Bridge Caverns is approximately one thousand feet above sea level, and the main level of the cave is more than one hundred-fifty feet lower. From the topography of figure 17, it appears that there is no area within a reasonable distance where the main cave level will intersect the surface. Thus, it appears that the cave was formed by purely phreatic processes (no, or minor, vadose contributions).

Figure 18 is a hydrologic map of Comal County with water level

*Flat-topped stalagmites approximately six inches in diameter with a yellow central portion, about two inches across, and a surrounding white rim. The color is probably due to the oxidation of iron in the water.
Figure 17: Location of Natural Bridge Caverns and Bracken Bat Cave

(Road and cavern location: personal communication from Mr. Harry Heidemann, U.S.G.S. topographic base map, Bat Cave, Texas, 1953.)
Figure 18: Groundwater Map of Comal County, Texas
(based on wells bottomed above the lower, massive, reef aquifer of the Glen Rose Limestone)

From: Rhoades and Guyton, 1955.
contours based on wells which do not penetrate the massive reef aquifer of the lower Glen Rose Formation. Because the ground-water is generally in artesian aquifers, the contours cannot be used to derive detailed flow lines, but they do indicate the approximate direction of flow (Rhoades and Guyton, 1955, p. 20). Note that most of the county drains to the southeast, approximately at right angles to the Balcones Fault Zone, but that a large area, outlined in red, will tend to converge and flow directly south through the location of Natural Bridge Caverns, which, for its main extent, also trends due south. The maximum quantity of this flow is evident in times of heavy rain when the water level in Purgatory Creek (see figure 16) may rise as much as thirty to forty feet (personal communication from Mr. Harry Heidemann). The only other areas in the county where the contours show such a convergence are surrounding the Guadalupe River, as expected, and near Bear Creek, where Dinosaur Cave is located.

As the ground-water converges, its flow rate must necessarily increase. The occurrence of Natural Bridge Caverns, the largest cave in the county, coincident with an area of high ground-water flow would seem to support Swinnerton's (1932) and Davies' (1957) hypothesis. However, from Thrailkill's (1968) conclusions this would seem to be purely circumstantial.

On the other hand, there is an ideal area for large amounts of vadose inflow, such as would support thrailkill's theory, where this converging ground-water passes under the course of Cibolo Creek, which is known to loose water underground very rapidly (George, 1952). However, in such a case, the cavern should be developed immediately
down-gradient from the source of vadose inflow and mixing. Natural Bridge Caverns is developed approximately one mile away and, even with its extensive known passages, there is little expectation that it will continue for another mile, especially with its passage size increasing as would be expected if Thrailkill's hypotheses were the cause. Therefore, even though the situation is modified by artesian conditions, I feel that the data support the role of high velocity ground-water flow in the formation of caves.

The level nature of the cavern could well have been caused by the level water table in the area, but it is more probably controlled by the bedding which is almost horizontal (less than \( \frac{10}{8} \) dip). The entrance sink of Natural Bridge Caverns is developed in the Edwards Limestone, but from the thin-bedded character of the strata exposed lower in the cave it appears that its main passages are developed within the upper Glen Rose.

An outcrop near Natural Bridge Caverns (figure 17) was identified by Dr. J.L. Wilson (personal communication) as the Walnut Clay, or its facies equivalent in this area. The section measured at that outcrop is as follows:

Dense, fine-grained, conchoidal fracturing, cream-colored limestone with occasional large (1-2 inches) oysters.

6" Cream-colored marl composed of 30% fine fossil debris in a
matrix of clay and micrite.

1' Irregular, lensey, limestone and marl.

3-4' Sandy, cream-colored marl with 15% quartz sand, 50% fossil debris and pellets, and 35% clay and micrite.

Dense, gray, conchoidal fracturing limestone with 20% coarse fossils, 40% pellets, 25% fine fossil debris, and 15% micritic matrix.

The elevation of the upper marl bed at this location is 1,001 feet above sea level.

A similar section was measured in the exit tunnel from Natural Bridge Caverns, as follows:

Dense, fine-grained, conchoidal fracturing, cream-colored limestone.

1' Cream-colored marl with 50% fine fossil debris in a matrix of clay and micrite.

4' Sandy, cream-colored marl with 5-10% quartz sand, 20% fossil debris, and 35% clay and micrite

Dense, gray, conchoidal fracturing limestone with 35% coarse fossils,
20% pellets, 10% fine fossil debris, and 35% micrite and sandy burrow fillings.

The elevation of the upper marl bed at this location is approximately 985 feet above sea level. Underground altimeter readings are commonly inaccurate due to the unusual temperature and pressure conditions existing there. However, the approximate similarity of elevations, lithologies, and sedimentary sequences indicates that the section measured in the exit tunnel is probably the Walnut Clay.

Assuming that this rock is the Walnut Clay, the two levels of major horizontal cavern development may now be approximately located in the stratigraphic column. Figure 19 is a portion of Test Well 4, as reported by Rhoades and Guyton (1955, figure 16). This well begins approximately seven feet below the lowermost Fredricksburg Group, which is the Walnut Clay. From the profile of Natural Bridge Caverns (figure 16), and allowing for development by breakdown, the upper passages are found to be between 72 and 92 feet below the Walnut Clay and the lower passages between 147 and 177 feet below. In addition, my laboratory analysis of a sample from the upper passage indicates that it is developed in a slightly dolomitic limestone (less than 20% dolomite). In the test well section there is a dolomitic limestone between 87 and 103 feet below the Walnut Clay and a shaly limestone between 162 and 342 feet below it. This does not agree precisely with my data derived from altimeter readings (15 feet of error in both cases), but by using the sample analysis to correlate, and considering
San Antonio Water Board Test Well 4; modified from: Rhoades and Guyton, 1955.
the error inherent in taking altimeter readings underground, I think
the two levels of cavern development may be placed in these lithologies
rather than in the overlying dolomites and shales or the intervening
dolomitic shales.

Summarizing my interpretation of the data which bear on the
development of Natural Bridge Caverns, it appears that this cave was
formed in the more calcareous beds of the Upper Glen Rose Formation
under the influence of high velocity ground-water flow caused by the
convergence of a large drainage area through this particular locale.

Bracken Bat Cave, developed nearby (see figure 17) is also
tentatively classed as a conduit cave. Many of the same circumstances
which occur at Natural Bridge Caverns are also found in Bracken Bat
Cave. Figure 20 is a map and profile of this cave and, using the
location on figure 17, a very approximate elevation for its entrance
can be found. The ceiling of the main passage is 66 feet below the
surface elevation, (figure 20). By subtracting this from the surface
elevation, approximately 1,040 feet above sea level, the elevation of
the ceiling is calculated to be 984 feet above sea level. This is
very close to the elevation of the Walnut Clay and substantiates the
former observation (Reddell, 1964, p. 1) that "the extremely flat roof
of Bracken is at the contact of the Glen Rose with the overlying
formation."

The uppermost portion of Test Well 4 (figure 19) is in hard,
gray limestone. Assuming that this extends upward to the Walnut
Clay, it would then have a thickness of twenty-seven feet. The
Figure 20:
BRACKEN BAT CAVE
Comal Co., Texas

Brunton & Tape Survey by
The University of Texas Grotto
1963

height of the main passage of Bracken Bat Cave is also twenty-seven feet (figure 20). Thus, it appears that the cave has been almost completely localized within this bed.

Like Natural Bridge Caverns, the entrance to Bracken Bat Cave is a large collapse sinkhole. In fact, the slope from the surface to the main cave level is entirely talus and the roof above rises in a series of bedding-plane steps to the surface. This evidence, although not as concrete as that for Natural Bridge Caverns, indicates that the original entrance was much smaller or non-existent. Thus, it was probably not responsible for the water flow which formed the cave. (Incidentally, the shaft above the dome in the south end of the cave is man-made and does not enter into these considerations.)

Bracken Bat Cave trends N. 23° W. (figure 20) which does not agree with the southward flow of ground-water through this area. However, this same trend is seen in portions of Natural Bridge Caverns (figure 16) and probably indicates minor jointing, developed locally, in that direction. The major joint patterns may be at too high an angle to the direction of ground-water flow to be involved in cave formation here.

The similarities between Natural Bridge Caverns and Bracken Bat Cave, in size, stratigraphic position, joint control, and location, suggest that their development is due to similar causes. Even though supporting data are meager, I feel that Bracken Bat Cave was developed within a suitable calcareous stratum by the converging (and, therefore, high velocity) ground-water flow through this area, and that flow was
directed along the most readily available joint. However, the case for this is not nearly as clear-cut as the same statement is for Natural Bridge Caverns and other suggestions may be equally applicable.

The third conduit cave in the upper Glen Rose of Comal County is Dinosaur Cave. Although I was not allowed access to the cave or its surroundings, there is an excellent map and a brief description by Reddell (1964, p. 20-22) on which the following discussion is based.

The entrance to Dinosaur Cave is located in a dry creek bed (figures 21 and 22). The cave trends approximately N. 67° E. as does the course of the stream. However, the entrance to the cave is at its northeast end, and the cave is developed unstream with regard to surface drainage and ground-water flow. Therefore, it does not appear that the mixing of the influent waters of the creek with the ground-water has formed the cave. However, figure 18 shows that Dinosaur Cave is also situated in an area of ground-water convergence which trends slightly north of east through this area.

Because the location of Dinosaur Cave is not known accurately, it is impossible to interpolate a reasonable figure for its elevation, and consequently it is impossible to place it in the stratigraphic column. However, it is formed primarily along joints trending N. 55° E. and N. 80° E. (figure 22) and these conform well with the published data on faulting and jointing (George, 1952; Boyer, 1967).

Conclusions regarding the formation of Dinosaur Cave must be tentative without further study but there is again a general agreement between high rates of groundwater flow and the formation of the
Figure 21: Location of Dinosaur Cave

Al Dinosaur Cave

Fredricksburg Group (Kf)
upper Glen Rose Fm.

Base map: George, W.O., 1952.

Miles

0 1 2
Figure 22:
DINOSAUR CAVE
Comal Co., Texas

Brunton & Tape Survey
by UTSS, 2-17-63

In summary, a hypothesis which agrees with the data on hand is that conduit caves in the upper Glen Rose Formation are formed by the action of large amounts of groundwater converging and flowing rapidly through a restricted area along joints which nearly parallel the gradient and dissolving the more calcareous beds through which it flows.
CAVES IN THE EDWARDS LIMESTONE

A number of caves exist in the Edwards Limestone in Comal County. Unfortunately, due to a lack of stratigraphic data on the Edwards facies in this area, and due to a lack of ground-water data for the Edwards outcrop area in this county, I was unable to examine the factors bearing upon the formation of these caves in any more than a cursory manner.

There appear to be representatives of all three types of caves in the Edwards Limestone: effluent, influent, and conduit. The factors bearing upon the origin of the effluent and conduit caves are far more interesting than those of the influent caves, and because there is no detailed stratigraphic section to which the latter caves can be related, they will not be discussed.

Three effluent caves are found closely associated near the point where Bear Creek passes under F. M. 2722. Beal Ranch Cave, which is still actively flowing, is located immediately above, or on, the contact of the Fredricksburg Group and the Glen Rose Formation. Like the other effluent caves in the county, Beal Ranch Cave is long, relatively horizontal, and partially filled with water. However, it does not appear to be associated with an artesian aquifer. The other two caves near it, Fault Falls Cave and Bear Creek Cave, are similar in occurrence and appearance, although the former cave is now dry.

For the mechanism of Gardner's theory of speleogenesis to operate it is not necessary to have an artesian aquifer. Apparently, a perched
aquifer will perform the same function. That is, the water may flow
down-dip over an impermeable stratum whether it is confined from above
or not. In fact, if it is not confined, it may flow in the up-dip
direction, providing the dip is low and the water table high (figure
23). This appears to be what has happened in the formation of the
aforementioned caves: the thin Walnut Clay has caused the water
table in the Edwards Limestone to be perched and where the contact
has been exposed by erosion or faulting, the water has spilled out
as springs. The continued flow would form effluent caves by a
process which is in some ways similar to Gardner's theory but has its
own distinctive modifications.

A group of caves, apparently conduit in origin, exists immedi¬
ately west of New Braunfels near Rt. 46 where beds overlying the
Edwards Formation are still found. These caves, R. R. Corith Cave,
Heidrich Cave, Brehmmer Cave, Little Brehmmer-Heidrich Cave, and Little
Gem Cave are well known, due to their proximity to the city of New
Braunfels. They are definitely not effluent, and, since all their
entrances apparently are due to collapse, they do not appear to be
influent either.

The localization of these caves with no primary surface con¬
nection appears to be due to the unconformity between the Edwards
and the Georgetown limestones. W. O. George states, "after the
Edwards Limestone was deposited, a part of the surface of the Edwards
was elevated above the level of the sea and was subjected to erosion.
During this period some of the upper part of the Edwards was removed
and a part of it became honeycombed and probably cavernous as a
Figure 23a: Speleogenesis due to the "tapping" of an artesian aquifer by a downcutting surface valley.

Modified from: Gardner, 1935.

Figure 23b: Speleogenesis due to the overflowing of a perched aquifer. Note: although the water table may fluctuate, it will reactivate the same channels (immediately above the impermeable strata) each time that it overflows.
result of solution by fresh water.... The importance of the disconformity in relation to ground water lies in the probability that the high permeability of the upper part of the Edwards Limestone, now buried beneath succeeding formations in the area south and southeast of the Balcones escarpment, may have been caused by solution during the interval indicated by the disconformity."

Probably this permeability localized ground-water flow and consequently caused the upper Edwards to undergo a second episode of localized karst development, even though covered by the Georgetown Formation.

To summarize this brief examination of caves in the Edwards Limestone, effluent caves exist immediately above the Walnut Clay-Edwards Limestone contact, apparently due to the perched nature of the Edwards water table in some localities. Other caves, which appear to be of the conduit type are found in areas where the upper, previously exposed portion of the Edwards is still present, apparently localized by this zone of high permeability. In addition, there are a large number of influent caves for which there is not enough data to make even the tentative hypotheses such as I have above.
SUMMARY

Caves in Comal County, Texas, may be divided into three categories: effluent caves, which are related to the flow of water from the ground-water reservoir to the surface; influent caves, which are related to the vertical flow of water from the surface to the water table; and conduit caves, which are related only to phreatic flow.

These three types of caves have separate and distinct origins. Effluent caves are forming in the lower Glen Rose Formation within a massive, fossiliferous, limestone aquifer. They are oriented generally down-dip and typify cavern formation by Gardner's (1935) theory of speleogenesis.

Influent caves are forming in both the upper and lower Glen Rose Formation. They develop in areas where the surface gradient is low and the infiltration consequently high. Influent caves develop vertically until they intercept a permeable stratum, generally limestone, which conducts the water laterally. A later change of conditions may cause additional deepening and a series of pits and passages may develop.

Conduit caves are forming in the upper Glen Rose Formation and are localized within the more calcareous strata. They occur only in areas of high ground-water velocity due to a convergence of the subsurface flow and are controlled by the joint system which is most compatible with the direction of that flow.
The conclusions reached in this report, even though it concerns an area of artesian conditions, may be related to the present theories of speleogenesis. Caves are forming within an artesian aquifer, oriented generally down-dip, thus substantiating Gardner's (1935) theory of speleogenesis, which has long been overlooked. Influent caves are most definitely related to the present topography and rapid ground-water flow appears to have an important role in the formation of conduit caves. The latter two points tend to validate the mechanisms proposed by Swinnerton (1932) and Davies (1957), even though their shallow-phreatic theory is not directly applicable.
SELECTED BIBLIOGRAPHY

Boyer, R. E., 1967, Interpretation of Joints and Airphoto Linear Features: abstract in Program of the First Annual Meeting of the South-Central Section of the Geological Society of America, Inc.


APPENDIX I

TEXAS SPELEOLOGICAL SURVEY STANDARD LEGEND

- Passage outlines
- Level other than main level, lower unless indicated
- Unsurveyed passage
- Sharp drop in floor level in hachured direction (vertical distance in feet)
- Sharp drop in ceiling; direction and amount indicated by ceiling heights
- Pit, with depth in feet
- Dome, with height in feet; if so indicated, pit entrance, with depth in feet
- Dome pit, with height over depth in feet
- Slope, down in splayed direction
- Large individual blocks of breakdown
- Masses of breakdown
- Gravel or very small breakdown
- Sand, silt, or dirt
- Clay
- Crystalline floor deposits
- Guano
- Ladder
Standard Legend (continued)

Steps

Soda straws

Stalactites

Stalagmites

Columns

Individual flowstone masses, stalagmites, or columns

Rimstone dams

Masses of flowstone on walls, or flowstone partitions

Standing water; lakes or pools

Direction and course of water flow in permanent stream (air flow, if so marked)

Direction and course of ephemeral stream

Waterfall

Siphon (cross-hatched)

Survey station

Ceiling height

Water depth

Depth below beginning point, usually entrance

Height above beginning point
Standard Legend (continued)

Profile trace

Cross-section of cave viewed in the direction shown by half-barbed arrow (cross-section rotated to the horizontal)

Cave (symbol used by U.S.G.S., Topographic Map Division)