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SPRING
1973

CAVES, KARST, AND GROUND WATER

by

St. Mary's University
of
Texas
Student Geological
Society

FOURTEENTH ANNUAL S.A.S.G.S. FIELD CONFERENCE

APRIL 6-8, 1973

ST. M. G. S.

CAVES, GROUND WATER, and KARST FEATURES of the CRETACEOUS IN SOUTH CENTRAL TEXAS

ST. MARY'S UNIVERSITY OF TEXAS
STUDENT GEOLOGICAL SOCIETY
SAN ANTONIO, TEXAS

PREFACE

The members of St. Mary's University of Texas Student Geological Society welcome you to the 1973 Spring S.A.S.G.S. field trip. We hope this will be an enjoyable and enlightening experience in your geological education.

The Southwestern Association of Student Geological societies was initiated by the Baylor Geological Societies with the first field trip in the spring of 1960. Membership in the Association is open to the student geological societies of universities and colleges of Texas and adjacent states. Participation in the annual spring field trip is the basis for membership, and any member society may host the field trip in their area. Those schools which have not yet hosted the trip are urged to do so. Previous field trips were hosted by Baylor, 1960; Midwestern, 1961; University of Texas, 1962; Hardin-Simmons, 1963; Pan American, 1964; Lamar Tech, 1965; West Texas State, 1966; St. Mary's University, 1967; Texas A & M, 1968; Hardin-Simmons, 1969; Pan American, 1970; Baylor, 1970 (Fall); University of Southwestern Louisiana, 1971; East Texas State University, 1972; and Baylor University, 1972 (Fall).

As we undertook this project, we found a surprising reservoir of talent in geology as well as in other fields, such as history, drawing, photography; and some who thought they couldn't -- found they could. We have been handicapped by student schedules at such odds with each other that it was a major operation just to find time for committees, much less the whole society, to meet. Our cadre of students with some class experience in the techniques of stratigraphy, paleo, and mineralogy has been pitifully small and we had to, at the outset, realize our limitations. Considering that most of our majors are sophomores, they have done an outstanding job.

It has been a frantic, frustrating, harried year -- asking the very most of all of us. In spite of all this, I wish to state that this has probably been the most interesting, informative, and maturing experience any of us will ever take part in throughout our academic lives; truly the finest learning medium I have personally encountered. We are grateful for the opportunity to share this in some way with you. We take full responsibility for any contributions to the enhancement of geologic knowledge as well as for any shortcomings in its pursuit.

Thank-you and enjoy the trip. If you have any questions or other problems, please contact one of the members of the

St. Mary's Society or myself.

R. Michael Clark, "The Big Drip"
St. Mary's University of Texas
Student Geological Society

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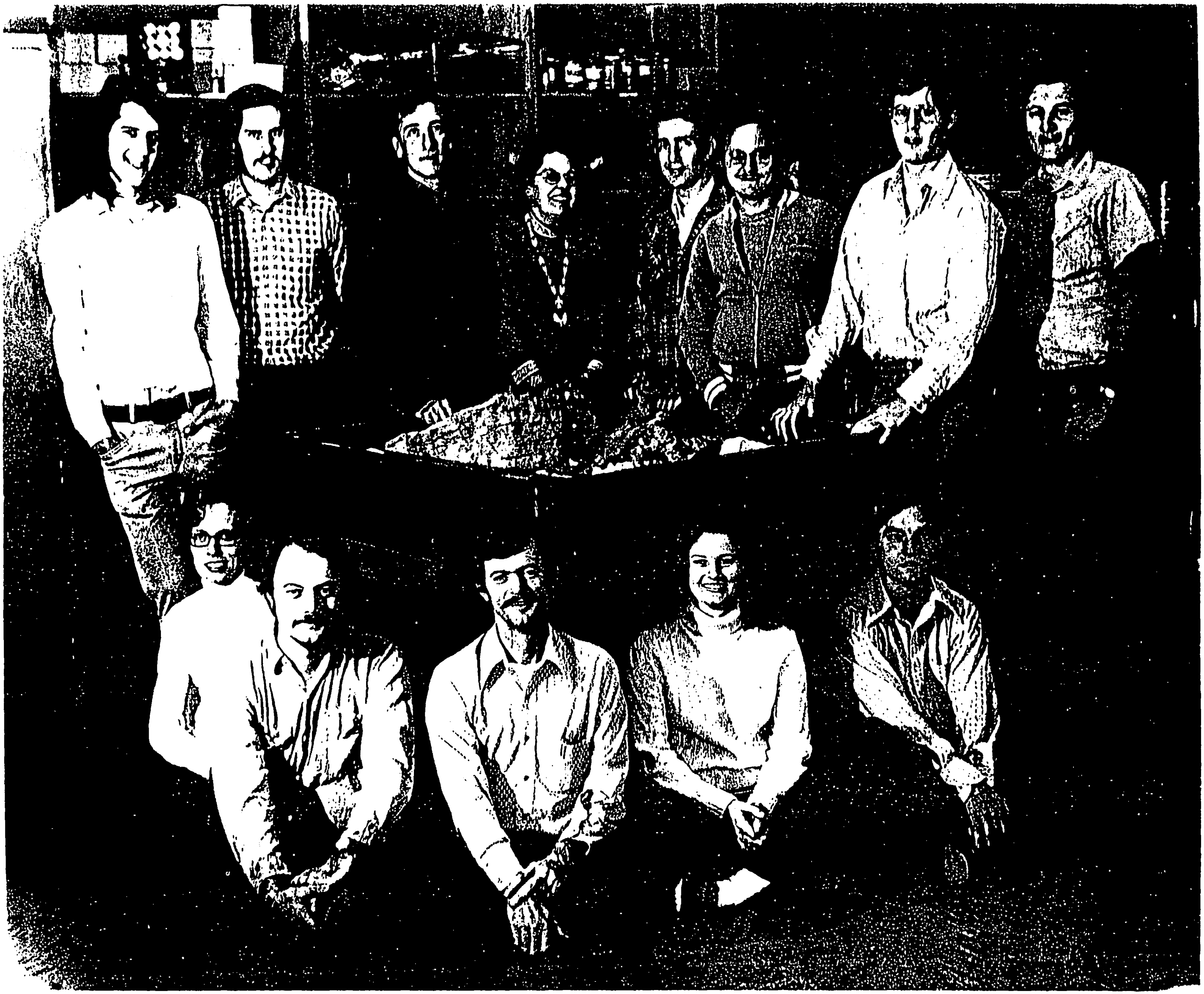


ACKNOWLEDGEMENTS

This undertaking, like all worthwhile endeavors, has needed and has received assistance and cooperation from a number of different sources which collectively have added to the success of this field trip. St. Mary's Student Geological Society would like to take this means and opportunity to say thank you to all and to give special acknowledgement to some of those to whom gratitude is due for their assistance.

COL. McD. D. WEINERT-EDWARDS UNDERGROUND WATER DISTRICT

MR. & MRS. HARRY HEIDEMAN-NATURAL BRIDGE CAVERNS

MR. PETER B. SAN FILIPPO-CYPRESS LAKE GARDENS

MR. & MRS. JOHN BRIDGES-CASCADE CAVERNS

JOHN H. NEWCOMB-THESIS: GEOLOGY OF THE BAT CAVE QUADRANGLE

MR. WILLIAM G. ELLIS-TECHNICAL CONSULTANT

We are thankful for the assistance of our advisors; Brother Robert Hanss, S. M., Dr. Preston Knodell, and Mrs. Sybil Lightfoot. We are especially grateful for the assistance given by Mrs. Lightfoot, without whose unselfish devotion of time and energy to the task, publication of this guidebook would have been impossible.

INTRODUCTION

R. Michael Clark

Karst Features

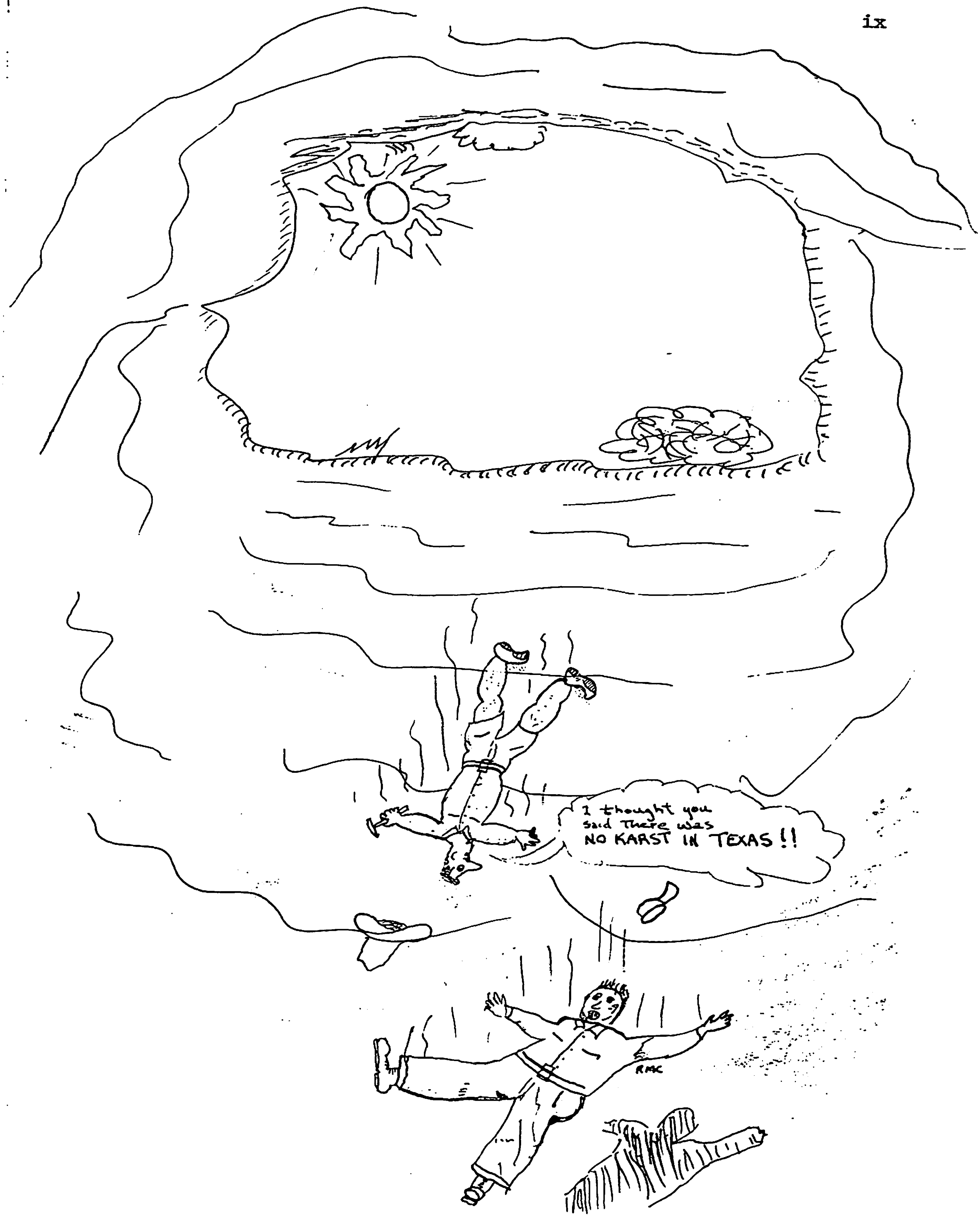
According to the Dictionary of Mining, Mineral, and Related Terms, published by the U. S. Department of the Interior (1968),

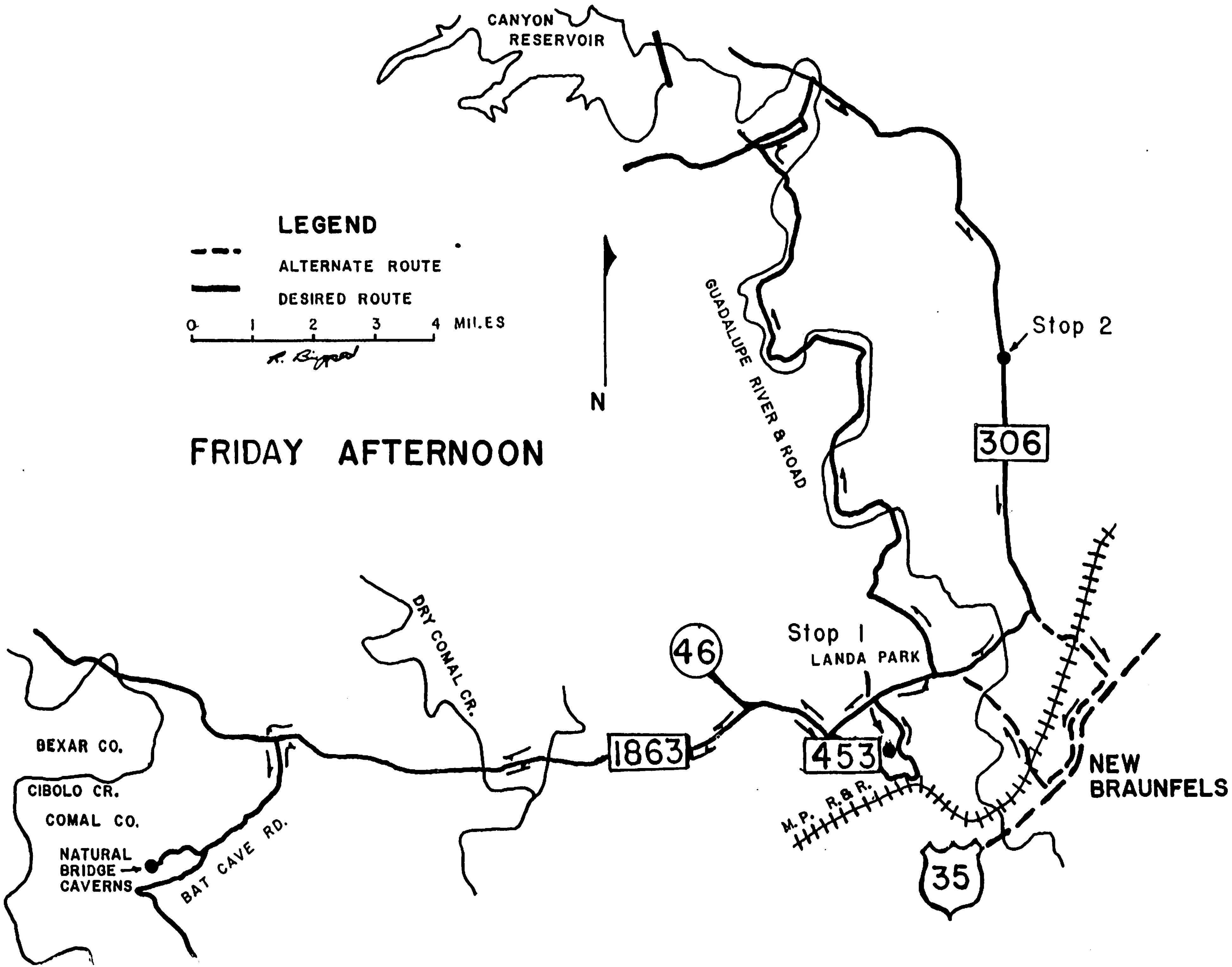
> "In Karst, on the eastern side of the Adriatic Sea, the limestone rocks are so honeycombed by tunnels and openings dissolved out by ground waters, that much of the drainage is underground. Large sinks abound, some of them 500 or 600 feet deep. Streamless valleys are common, and valleys containing streams often end abruptly where the latter plunge into underground tunnels and caverns, sometimes to reappear as great springs elsewhere. Irregular topography of this kind, developed by the solution of surface and ground waters, is known as karst topography."

Limestone is virtually insoluble in pure water. Ground water, however, is not pure, insofar as it usually contains such agents as humic acid derived from the surface vegetation. This solution with the right conditions of pressure and temperature, convert limestone to a bi-carbonate whose molecules can travel in ground water until the proper threshold of pressure and temperature is reached wherein the bicarbonate returns to the carbonate state. For example, a stalagtite may suddenly cease to form and return to an amorphus calcite.

Textbooks of Geomorphology by such noted geologists as Thornbury (Regional Geomorphology of the United States, 1965, John Wiley and Sons, Inc.); Wyckoff (Rock, Time, and Landforms, 1966, Harper and Row.); and Easterbrook (Principles of Geomorphology, 1969, McGraw-Hill.), invariably omit a discussion of the Edwards Plateau as a karst area. Perhaps this may be due to the physical size of the region, however, by definition, this region is rich in the features defining karst. There are numerous sink holes, dry creek beds, disappearing streams, springs, large caverns, and one distinct uvala (Edge Falls).

With respect to karst areas such as the state of Chihuahua in northern Mexico, southeast New Mexico near Roswell, and the Mammoth Cave area of Kentucky, the Edwards Plateau gives evidence of karst features in youthful form. Perhaps the most influential environmental aspect of its youth is the lack of humidity and rainfall in the area. The Edwards Plateau is divided longitudinally by the twenty-thirty inch rainfall line, and the karst features to the west of this line are far less developed than those to the east, with the possible exception of the area around the Caverns of Sonora.


I thought you said There was NO KARST IN TEXAS!!
RMK

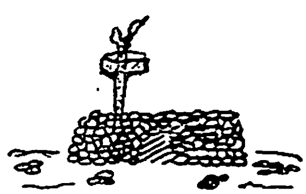


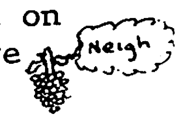
CANYON RESERVOIR
LEGEND
ALTERNATE ROUTE
DESIRED ROUTE
0 1 2 3 4 MILES
FRIDAY AFTERNOON
N
GUADALUPE RIVER & ROAD
Stop 2
306
DRY COMAL CR.
46
Stop 1
LANDA PARK
1863
453
M.P. R.R.
NEW BRAUNFELS
35
BEXAR CO.
CIBOLO CR.
COMAL CO.
NATURAL BRIDGE CAVERNS
BAT CAVE RD.

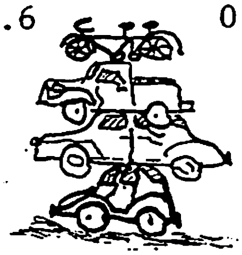
FRIDAY ROAD LOG

Assemble cars on the south side of the road, headed east, just west of archway entrance to Natural Bridge Caverns.

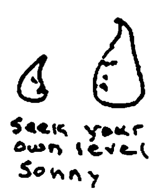
Cumulative Mileage	Interval Mileage	
0.0	0.0	On your mark! Get set! Turn right!
0.1	0.1	At stop sign turn left onto Bat Cave Road. Bat Cave Fault parallels this road on the left (west) side about 100-150 yards off the road for approximately 1.5 miles.
1.6	1.5	Bat Cave Fault crosses the road trending from SSW to NNE.
2.4	0.8	Stop sign. Turn right onto FM 1863.
3.4	1.0	Bat Cave Fault crosses FM 1863.
5.9	2.5	Road enters from right, continue on FM 1863.
6.8	0.9	Low water crossing.
7.5	0.7	Road enters from right, continue on FM 1863.
7.8	0.3	On the left is a stone wall built of native rock. There are many examples of this use of limestone throughout the countryside. When the Unitarian Church was built in San Antonio the Board of Directors simply bought a fence and built the church of the rock.
8.5	0.7	Road enters from the left, continue on FM 1863. The trees of this area are covered with Mustang grape vines.
9.4	0.9	Evidence of urban expansion is seen in the increasing number of new homes built along this road.





10.7	1.3	Stop sign, turn right onto FM 46.
12.0	1.3	Intersection of Loop 337 and FM 46. FM 46 becomes Business 46, continue straight ahead.
12.6	0.6	The Guadalupe River can be seen on the right. To the left is an outcrop of the Buda limestone.
13.3	0.7	Stop sign, turn left onto Landa Street.
13.7	0.4	Railroad crossing.
13.9	0.2	At signal light turn left onto Landa Park Road. The power plant on the left harnesses energy from Landa Park Springs.
14.1	0.2	On the right is New Braunfels' Wurstfest Hall. Last year more than 125,000 people came here to eat, drink, and be merry.
14.3	0.2	Cross over park bridge. Spanish moss grows on the trees in this area but is not parasitic.
14.5	0.2	Cross park bridge (#2)
14.6 	0.1	<u>Stop I.</u> Please park as directed by coolies. Refer to Comal Springs report page 8A. Return to cars. Please unpark as directed by coolies!
14.7	0.1	Comal Springs Fault crosses road.
15.6	0.9	Stop sign, turn right onto Loop 337.
16.7	1.1	Flashing light, turn left onto River Road.
16.9	0.2	Low water (we hope) crossing of highly competent stream.
17.0	0.1	Texas mail box on the right. Mr. R. T. Moore receives "Moore" mail from friends who write long letters.

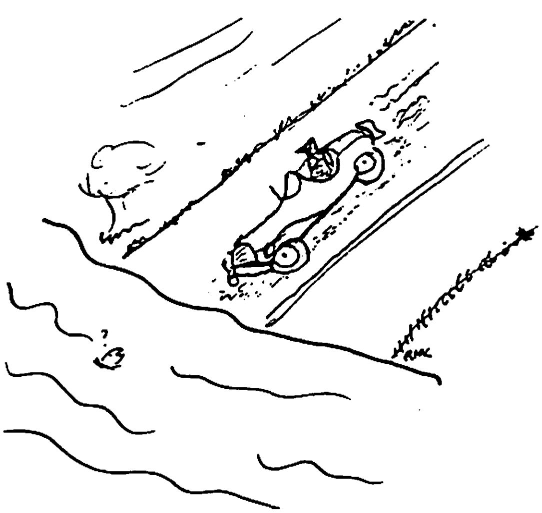
17.2	0.2	Deer fence along the left side of the road prevents deer from entering or leaving property.
18.5	1.3	Hueco Road enters River Road from the left. River Road curves right, continue on River Road.
18.7	0.2	Cedar trees grow abundantly in this area of the Guadalupe River valley.
19.0	0.3	Slumber Falls Camp Road enters from the right. Continue on River Road.
19.2	0.2	Cross bridge over intermittent stream which flows into the Guadalupe River. To the immediate left is a small dam which has been damaged by flooding. Water borne debris tangled high in trees and bending in the downstream direction are the result of past flooding of the Guadalupe River.
19.5	0.3	Edwards limestone cliffs on the right. Non-resistant beds have been eroded by ground water percolation and by the river closer to the base of the cliff. This is also the immediate area of the Hueco Springs. The springs issue from stream gravels in two places, one about 400 feet an and the other about 200 feet west of the river. The westernmost spring comes to the surface at an altitude of about 645 feet above sea level and is about 4 feet above the bed of the river; the other spring is nearer the river and is about 10 feet higher than the stream bed. The springs appear to rise a few feet north of the Hueco Springs Fault, having several hundred feet of displacement, the trace can be seen in the river bed. In dry years the springs are dry for months at a time. The temperature of Hueco Springs fluctuates as much as 3°F. The water is ordinarily clear but becomes slightly turbid during the first flow after heavy rains.



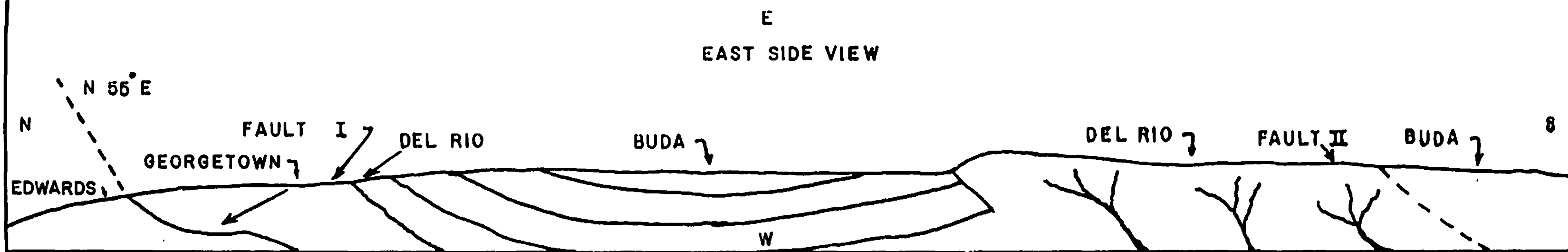
19.9	0.4	Bridge crossing. On the east side of the river Isaac Creek, an intermittent stream, empties into the Guadalupe. This creek has carved steep channels into the Edwards limestone. The 150 foot cliff east of the bridge consists of small caves, boxwork, and a very large talus on the slope.
20.0	0.1	In the cliffs on the right are solution cavities, excellent examples of the work of water on limestone.
20.3	0.3	The cliffs on the left are approximately 250 feet high and are made up of Edwards and Comanche Peak limestone.
20.6	0.3	On the right are Pleistocene river deposits of the Leona formation. The Leona is composed of limestone gravels, sand and clay arranged in terraces by the present streams in their valleys. The terraces overlie all formations crossed by the streams and the formations range in thickness from a fraction of an inch to a probable maximum of 65 feet. The Leona is found mainly in the valleys of the Guadalupe River and Cibolo Creek. In the valleys above the escarpment formed by Comal Springs fault, the Leona fills old abandoned meander channels and is rarely used as a source of water, probably because of leakage into underlying rocks and drainage into the streams.
21.1	0.5	Cliffs on right with extensive solution work. The Edwards, together with the Comanche Peak limestone, forms the walls of the Guadalupe River canyon above Hueco Springs. The Edwards and Comanche Peak limestones are very similar so well drillers do not distinguish between them in Comal County. The Edwards lies conformably upon the Comanche Peak limestone. The thickness of the Edwards in Comal County is from approximately 350 to 500 feet. The outcrop area is mostly in the southeastern part of the county.

21.5	0.4	River Road camp and picnic grounds line the Guadalupe River. The Guadalupe in this area contains several small rapids.
21.9	0.4	Sharp left turn, cross bridge. In the river to the left of the bridge is a sand bar created due to the change in flow of the river.
22.0	0.1	Sharp right turn. We are now crossing onto the upthrown side of Bat Cave Fault. The cliffs on the left and upstream from this point are at the base Upper Glen Rose limestone and at the top the Fredericksburg group (Edwards and Comanche Peak). Bat Cave Fault enters the eastern boundary of the county about 2 miles north of the Comal Springs Fault, crosses the Guadalupe River about 2 miles north of Hueco Springs, and crosses the western boundary of the county 5½ miles northwest of Bracken in the vicinity of Bat Cave.
22.5	0.5	Alluvium deposit on the left.
22.7	0.2	Small rapids on the right are an indication of recent faulting.
22.8	0.1	The Glen Rose limestone cliffs on the left are covered with moss growth.
23.2	0.4	The Guadalupe River has cut down through bedrock creating a natural dam and rapids.
23.5	0.3	Alluvium deposits on the left. The cliffs on the right display characteristic resistant and non-resistant bedding.
24.2	0.7	Wide fertile floodplain.
24.4	0.2	On the left is a deep intermittent stream bed with large limestone rocks washed down from the hills. Vertical hills are of Upper Glen Rose capped with heavily eroded Fredericksburg group.

24.9	0.5	Bridge crossing Guadalupe River.
25.0	0.1	The exposed alluvium on the right alternates between fine clay particles to rocks up to 4 inches in diameter.
25.4	0.4	Camp Beans resort located on the left.
25.5	0.1	Cross cattleguard.
25.7	0.2	On the right is a massive outcrop of Edwards limestone.
25.8	0.1	Slumping has occurred in the alluvium deposit on the right. Just beyond the alluvium there is a large mass of upturned limestone beds that have slid down the steep cliff in recent geologic time.
26.5	0.7	Cross cattleguard.
26.7	0.2	More alluvium on the right.
26.9	0.2	Glen Rose cliffs on the right.
27.3	0.4	On the left is a dipping concrete bridge built as access to newly developed areas.
27.5	0.2	Jacobs Creek, an intermittent stream flows into the Guadalupe River.
28.1	0.6	Cross cattleguard.
28.3	0.2	Low water crossing. This is the area of the Bear Creek Fault. This fault crosses the Guadalupe River about a mile southwest of Sattler. Between the Bat Cave Fault and the Bear Creek Fault the thickness of the Edwards limestone has been considerably reduced by erosion; and in the deeper valleys the streams have cut through both the Edwards and Comanche Peak limestones into the top of the upper member of the Glen Rose. The Glen Rose within this block dips southeastward and is higher than the water level in the Edwards southeast of Bat Cave Fault.

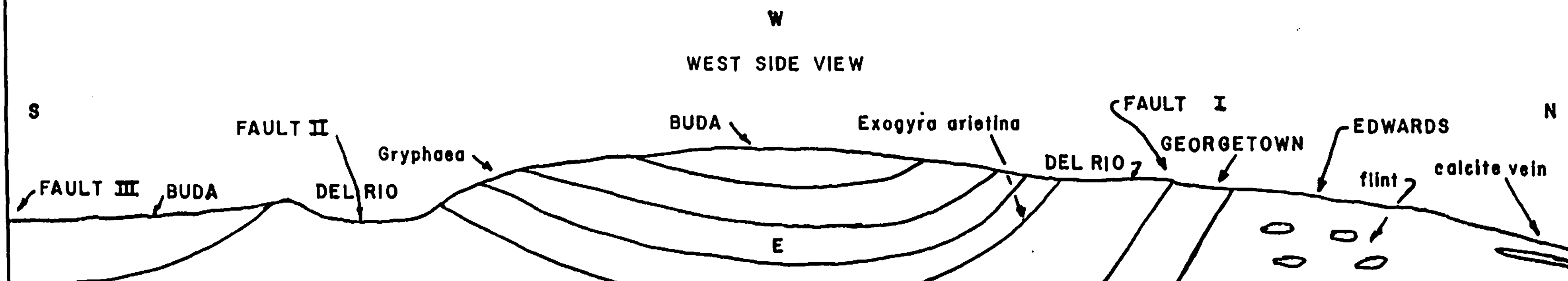


28.8	0.5	Turn left, cross bridge.
29.2	0.4	Road forks, take right fork (straight ahead).
29.3	0.1	Stop sign, turn right.
30.0	0.7	Turn left at Kanz Store then turn right onto FM 2673.
30.6	0.6	Stop sign, turn right onto FM 306.
30.8	0.2	Cross Guadalupe River. Rapids appear upstream.
31.1	0.3	Upper Glen Rose limestone roadcut.
31.3	0.2	Cross Cordova Hollow Creek bed.
31.6	0.3	Cross intermittent stream. This area enters the downthrown side of Bear Creek Fault.
32.0	0.4	Edwards and Comanche Peak roadcut.
32.8	0.8	Edwards and Comanche Peak roadcut.
33.6	0.8	Purgatory Road enters from the left, continue straight on FM 306.
34.5	0.9	KLRN radio tower on the right.
36.3	1.8	<u>Stop II.</u> Please park on right shoulder of road. Refer to "Gray's Fault" report page 17A. Return to cars--Please use caution when pulling onto highway.
37.4	0.7	In this area prickly pear cactus and mesquite trees are abundant.
39.4	2.0	Cedar and oak trees are covered with Spanish moss and Ball moss. Neither type is parasitic.



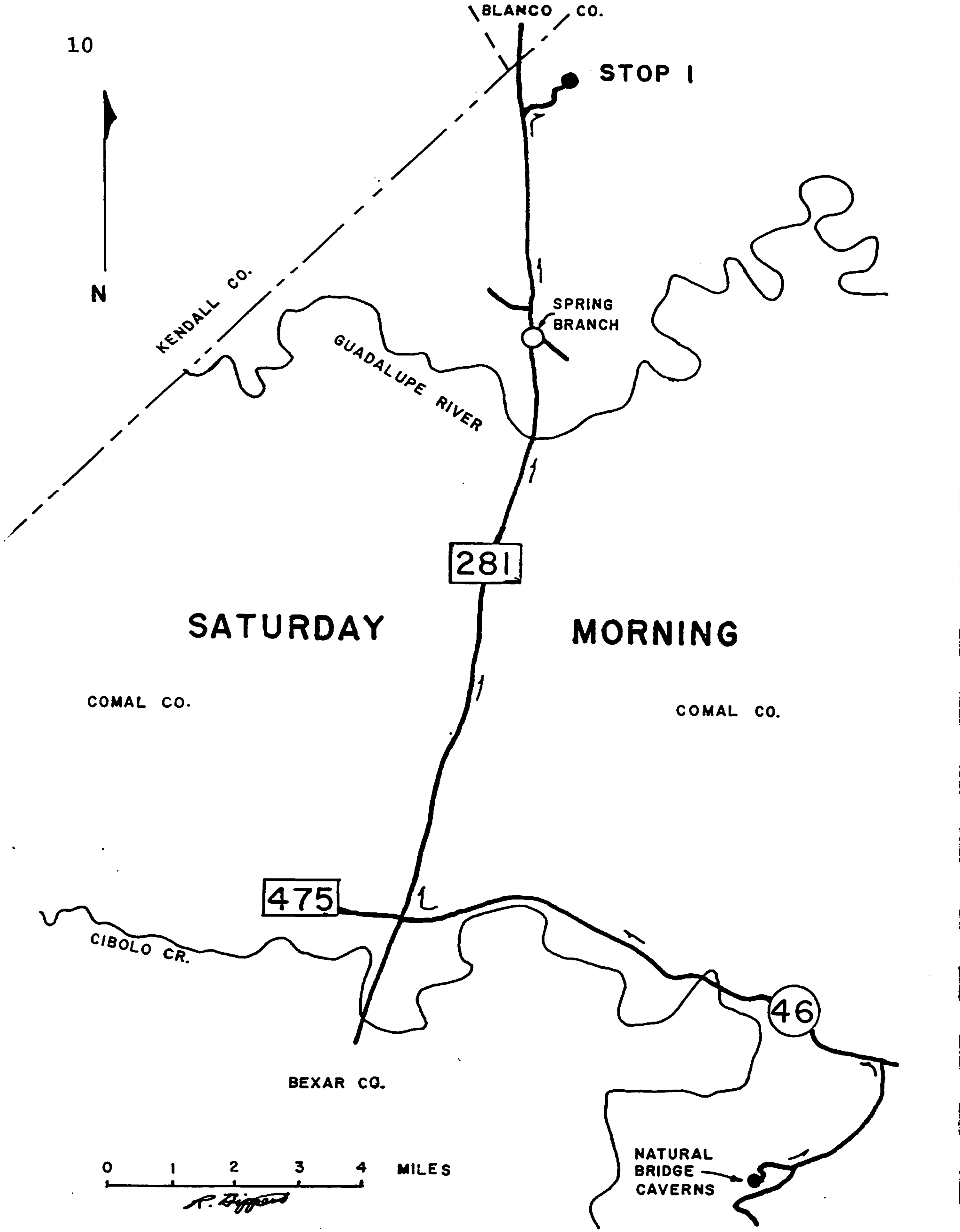
This graben affords us an excellent view of a stratigraphic section of the Washita group. The normal sequence of deposition is Edwards limestone, Georgetown limestone, Del Rio clay, and Buda limestone.

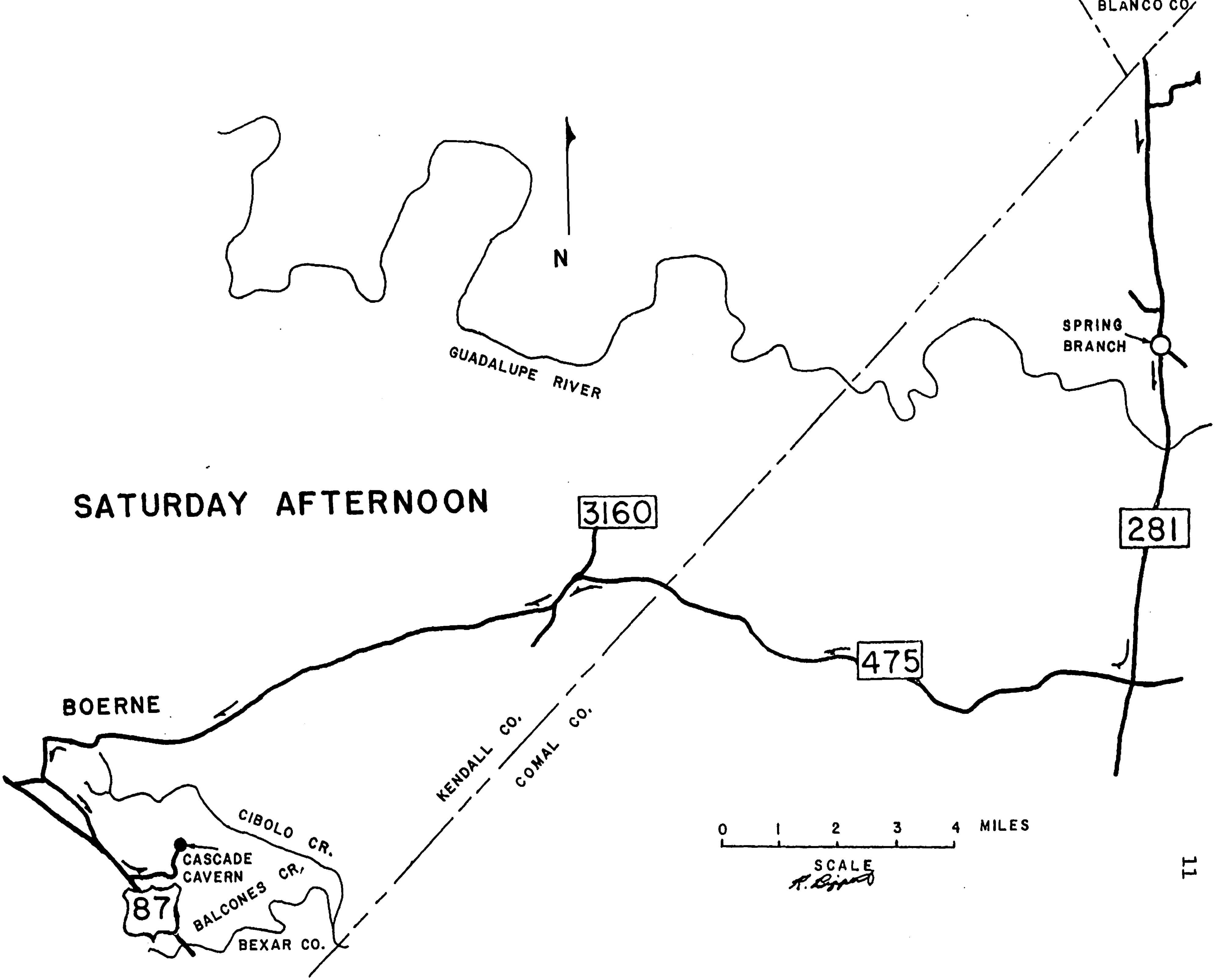
There is evidence of three normal faults in this location. The first major fault (Fault I) occurs at the contact between the Georgetown limestone and the Del Rio clay. The second (Fault II) occurs on the opposite side of the graben and is contained in the Del Rio formation. The third (Fault III) is not exposed. However, there is evidence which suggests that it is south of the road cut.



The faults connected with this graben are an extension of the Bat Cave Fault which strikes approximately N 55° E and at this location has an estimated total displacement of 100 feet.

40.1	0.7	On the right is terracing for crop growth.
40.6	0.5	Abundant cedar growth.
41.1	0.5	Railroad crossing and dump.
41.3	0.2	Crossroad, turn right.
41.7	0.4	Turn right at stop sign.
41.8	0.1	Sharp left turn.
41.9	0.1	Cross bridge. The small waterfalls are caused by rock in the streambed.
42.5	0.6	Main road veers left. Continue straight ahead onto secondary road. Cross railroad tracks.
42.7	0.2	Turn right onto Loop 337.
42.9	0.2	KGNB and KNBT radio station on the right. Roadcuts of Fredericksburg group.
43.1	0.2	River Road intersection. Continue on Loop 337.
44.9	1.8	On the left is New Braunfels High School and Stadium.
45.1	0.2	Take Junction 46 Exit to access road.
45.4	0.3	Turn right onto Texas 46.
46.8	1.4	Turn left onto 1863.
47.5	0.7	Turn left onto Bat Cave Road.
49.8	2.3	Turn right to Natural Bridge Caverns.
50.0	0.2	Sharp left turn.
50.1	0.1	Turn right to enter Campgrounds.


BLANCO CO.
STOP 1
N
KENDALL CO.
SPRING BRANCH
GUADALUPE RIVER
281
SATURDAY MORNING
COMAL CO.
COMAL CO.
475
CIBOLO CR.
46
BEXAR CO.
0 1 2 3 4 MILES
NATURAL BRIDGE CAVERNS

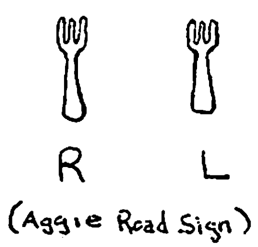


SATURDAY AFTERNOON
BLANCO CO.
N
GUADALUPE RIVER
SPRING BRANCH
3160
281
475
BOERNE
KENDALL CO.
COMAL CO.
CIBOLO CR.
CASCADE CAVERN
BALCONES CR.
87
BEXAR CO.
0 1 2 3 4 MILES
SCALE

SATURDAY ROAD LOG

Assemble on the veranda outside the gift shop of Natural Bridge Caverns at the time you have been assigned. When all attendees have toured the caverns, we well reassemble at the red archway entrance to Natural Bridge. Please line up behind the lead vehicle facing east along the NBC access road.

Cumulative Mileage	Interval Mileage	
0.0	0.0	Take the left fork from the Red Arch. This is the approximate location of the northeastward-trending Bat Cave Fault. Exposed on the surface of the upthrown side of the normal fault is the Kainer formation, Rose (1968, p. 33)-(Lower member of Edwards). On the downthrown side of the fault is the Dr. Burt member of the Person formation, Rose (1968, p. 38)-(Upper member of Edwards). The Dr. Burt member directly overlies the Kainer. The Edwards bedrock on the hillsides is typical for this region of the state. Since the soils are too thin and the topography too rough for farmland, most of the land is left as it is. These rocks are hard white limestone, totally lacking in megafossils.
0.1	0.1	Stop sign, turn left onto Bat Cave Road. The Bat Cave Fault is paralleling the road on the left side. Exposed on the upthrown side is the Walnut Clay. The formation is in neritic facies over most of its strike. It is made up of clays, shell aggregates, and limestone seams. Typical fossils are <u>Exogyra texana</u> and <u>Gryphaea marcoui</u>. The Kainer formation is exposed on the downthrown side of the fault.
1.6	1.5	The Bat Cave Fault crosses the road where the road curves to the left. As we proceed up the hill we pass over the Walnut and then the Kainer.



2.3	0.7	Walnut clay outcrop on the right. No megafossils have been found at this outcrop.
2.4	0.1	Turn left onto FM 1863.
3.0	0.6	The hills to the left are formed by the resistant Kainer formation which overlies the fairly soft Walnut Clay. Between the road and the cliffs, Quaternary alluvial deposits form the lowland. Throughout the area streams have cut their way through the alluvium to the lower bedrock.
3.4	0.4	West Fork Creek, an eventual tributary to the Comal River and then the Guadalupe.
3.7	0.3	To the left is an outcrop of the dark, blocky Kainer. The rocks strewn about the countryside are also Kainer.
4.3	0.6	A change in vegetation to dense cedar and oak trees occurs in this area. The peaks of the hills on the right side are 100 to 125 feet higher than the road and are capped by the Kainer limestone.
4.5	0.2	This outcrop consists of soft yellowish tan marly layers alternating with hard, dark, blocky limestone. Small 1" solution holes are found in the hard limestone.
4.9	0.4	Chert was found in the Kainer outcrop to the right but no megafossils are evident.
5.0	0.1	Tributary to Cibolo Creek. Although this creek is usually dry at this location, the slump caused by the combination of rain and too steep a cut in the alluvium is evidence of past heavy flow. The Highway Department should have done some better planning at this location.
5.2	0.2	Cross over Cibolo Creek. The flood gauge indicates the competancy of this stream and gives some idea of the damage that can be caused by a bad storm in this area.

		The width of the stream at this location is about 40 yards. The material on the bottom of the creek bed consists of gravel, small rocks, and broken concrete slabs. The stream bottom is in the very top of the Glen Rose limestone.
5.5 *Note - Measured section and description appears on pp. 22-26.	0.3	The high cliff to the right consist of Glen Rose limestone at the base, the Walnut about 50 feet at the middle, and the Kainer formation capping the hill. The total height of the cliff above the stream bed is around 180 feet.
5.7	0.2	Cross over Cibolo Creek again. On the right side of the road is a cliff caused by the Zaccaria Ranch Fault. The northeastward trending normal fault is hidden under the Quaternary alluvium. The Glen Rose, Walnut and Kainer are exposed in this 275 foot section.
5.9	0.2	The alluvial flood plain on the left is used for farmland however, most of this area is used for ranching and hunting.
6.4	0.5	This is the approximate location of the Hidden Valley Fault which parallels the Zaccaria Ranch Fault. It, too, is a normal fault with the upthrown side on the northwest. Since Glen Rose is exposed on both sides of the fault it is hard to pinpoint the exact location of the fault. The average displacement along this fault is 200 feet.
6.8	0.4	Outcrop of Upper Glen Rose on the left. Very few fossils are found in this buff-yellow, soft limestone exposure.
7.4	0.6	"Running Deer" road enters from the right. Continue on 1863.
7.8	0.4	"Prancing Deer" road. Continue on 1863.
7.9	0.1	Cross over a low water bridge. The small rocks on the stream botton and the absence

		of any large rocks plus the flora in the stream bottom are good evidence of a stream which rarely has much capacity or competance.
8.0	0.1	"Oak Valley" road enters from the right. Continue on 1863.
8.4	0.4	On the left is the floodplain of the Cibolo Creek.
8.5	0.1	"Oak Ridge" road enters from the right. Continue on 1863. These roads are a part of the Oak Village North land development. As San Antonio grows over the next few years these lots will undoubtedly become more valuable to both land speculators and home owners. The accessibility of this area to Highway 281 offers easy commuting to the businessman who desires to live in the country but work in the city.
8.7	0.2	"Smithson Valley" road enters from the right. Continue on 1863. This road connects 1863 and Highway 46 to the north in the town of Smithson Valley.
8.8	0.1	"Starlight" road enters from the right.
8.9	0.1	Cross over a dry creek bed.
9.0	0.1	On both sides of the road are Upper Glen Rose outcrops.
9.1	0.1	The floodplain of Cibolo Creek is encountered just past this exposure. The contrast in plant growth, shrubs and small trees on the bedrock and farmlands on the floodplain can be seen at this location.
9.4	0.3	Located about one mile directly south is Vogels Peak with an elevation of 1360' above mean sea level. A radio tower has been built on the summit making use of both the height and the resistant Kainer formation.

9.8	0.4	Low water crossing for a minor tributary to Cibolo Creek.
10.1	0.3	To the right just off the road is the Hitzfelder Cemetery with stones dating back to 1824. Many young children from 1 to 8 years of age are buried here. One of these is Karl G. Uecker who was born on April 6, 1904 and died the following March. His tombstone, written in German and translated: "Now I lie in poor wormcloth and sleep in my small room. I went through an easy death contrary to fear and misery.", is typical of inscriptions used for children. About half a dozen other cemetaries are also located in this vicinity, the majority being small family plots used by the German-American residents in this area.
10.2	0.1	The streambed of Cibolo Creek runs parallel to the left side of the road.
10.9	0.7	Junction. Turn right onto Hwy. 281N.
11.5	0.6	Upper Glen Rose limestone is exposed in the roadcuts for the next 4 miles. No unconformity was observed between the upper and lower members of the Glen Rose limestone. The upper member is comparatively barren of fossils. <u>Orbitolina texana</u> occurs irregularly in five or six beds and a few other beds are fossiliferous, but in the upper part of the upper member no fossils are found. Ripple marks, cross-bedding, and other manifestations of shallow-water deposition are common. The maximum yield for most water wells in the upper member of the Glen Rose in this area is probably less than 3 gallons per minute. However, in some places where the main channels of the reservoirs in the Edwards and Comanche Peak limestone overlie thin beds of Walnut clay, it is believed that solutional cavities extend down into the upper member of the Glen Rose limestone. (Excerpts from <u>Geology and Groundwater Resources of Comal County</u>,

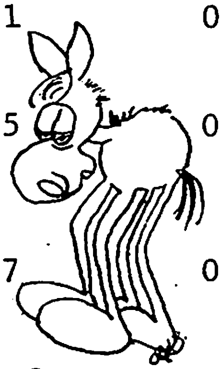
Texas, by W. O. George, S. D. Breeding and W. W. Hastings, Water Supply Paper 1138, 1952.) Wells in this area are used for stock and residential purposes. Most of the wells are six inches in diameter. The water level is from 675 feet to 750 feet above mean sea level, or around 250 to 300 feet below the surface of the ground.

13.1	1.6	Casey Road enters 281 from the left. Continue on Hwy. 281.
14.7	1.6	Junction of 46 and 281. Continue ahead on Hwy. 281.
15.8	1.1	This Glen Rose roadcut contains a very fine exposure of the Salenia texana zone which marks the boundary between the upper and lower members of the Glen Rose. The following species were collected at this site and identified by members of the United States Geological Survey:

Orbitolina texana (Roemer)
Salenia texana (Credner)
Tetragramma sp.
Hemiaster comanchei (Clark)
Enallaster texanus (Roemer)
Prohinnites sp.
Nuculana
Panope df. P. Hensilli (Hill)
Homomya jurafacies (Cragin)
Artica medialis (Conrad)
Artica roemeri (Cragin)
Idonearca cf. I. terminalis (Conrad)
Idonearca sp.
Volsella sp.
Protocardia sp.
Neithea occidentalis (Conrad)
Pteria sp.
Trigonia crenulata (Roemer)
Apporhais sp.
Nerinea sp.
Nerinea n. sp.
Lunatia praegrardis (Roemer)
Tylostoma so.
Porocystis globularis (Giebel)

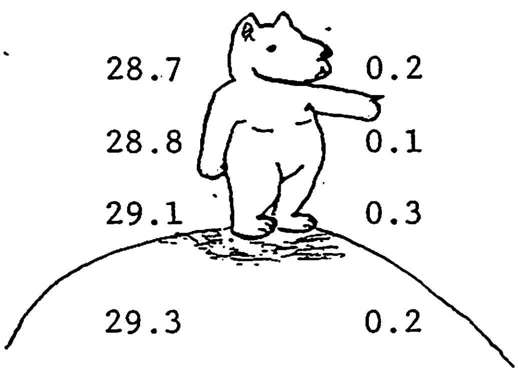
16.2	0.4	On the left is Bates Ornamental Bird Bath and Statuary Shop.
16.9	0.7	Gravel road enters from the left. Continue on 281.
17.3	0.4	Lower Glen Rose roadcut.
17.4	0.1	Hwy. 281 divides.
17.9	0.5	"Cattle Call" diner is to the right and is better known as "Red Neck Heaven--Long-hair's Hell".
18.6	0.7	Cross over the Guadalupe River. Terraces of the Guadalupe River are made up of the Pleistocene Leona formation. (The terraces along Cibolo are of this same formation.) The name Leona was given by R. T. Hill and T. W. Vaughan in 1898 to include terrace deposits along the principal streams of Texas. The deposits are composed of red and reddish-grey silt and fine gravel. Vertebrate remains and fresh water mollusks are common in these sand and silt layers. The vertebrate remains, according to O. P. Hay (1923) are indicative of early Pleistocene time and are approximately equivalent to the Sheridan beds of Nebraska. (Excerpt from <u>The Geology of Texas</u>, Bulletin 3232, Texas Bureau of Economic Geology, 1932.) The maximum thickness of the formation is probably less than 65 feet. The Leona is rarely used as a source of water for wells, probably because of leakage into underlying rocks and drainage into streams.
19.3	0.3	Divided highway ends.
20.0	0.8	Cross over Cypress Creek.
20.1	0.1	Junction of 311 and Hwy. 281. Continue on 281. The Spring Branch Fault, which trends northeasterly, crosses 281 in this vicinity. This fault is actually two faults paralleling each other. Maximum displacement is around 200 feet.

20.6	0.5	Entering from the left is Spring Branch Road. Continue on Hwy. 281. Spring Branch Road leads to Edge Falls, a uvala through which Curry Creek flows.
21.1	0.5	The roadside park on the left was donated by Herman Knibbe Sr. in memory of the Knibbe family.
21.8	0.7	The fieldstone house and barn on the left are very good examples of the use of stone for building purposes. The pasture land of this area is used for sheep raising.
22.9	1.1	Cross over a minor tributary to Cypress Creek. The water of this creek flows into the Guadalupe River.
23.2	0.3	Intersection of 281 and Rebecca Creek Road. Turn right onto Rebecca Creek Road. This area is Cypress Lake Gardens, a land development that provides for homesites without disturbing the beauty of the land.
23.6	0.4	Cherry Creek Ranch located on the left.
24.2	0.6	Crossing Spring Branch Fault.
25.4	1.2	Entrance to Cypress Lake Gardens.
25.7	0.3	Rocks piled around the trees are for decorative rather than beneficial purposes.
26.0	0.3	Stables and ranch house located on right side of road.
26.1	0.1	Intersection of Rebecca Creek Road and Park Drive. Turn left onto Park Drive.
26.5	0.4	Cross creek and make a sharp right turn. A camping and picnic area used for residents is located along this road.
26.7	0.2	On the left is an exposure of Cow Creek limestone. There is evidence of springs on the ledge at this bedding plane.

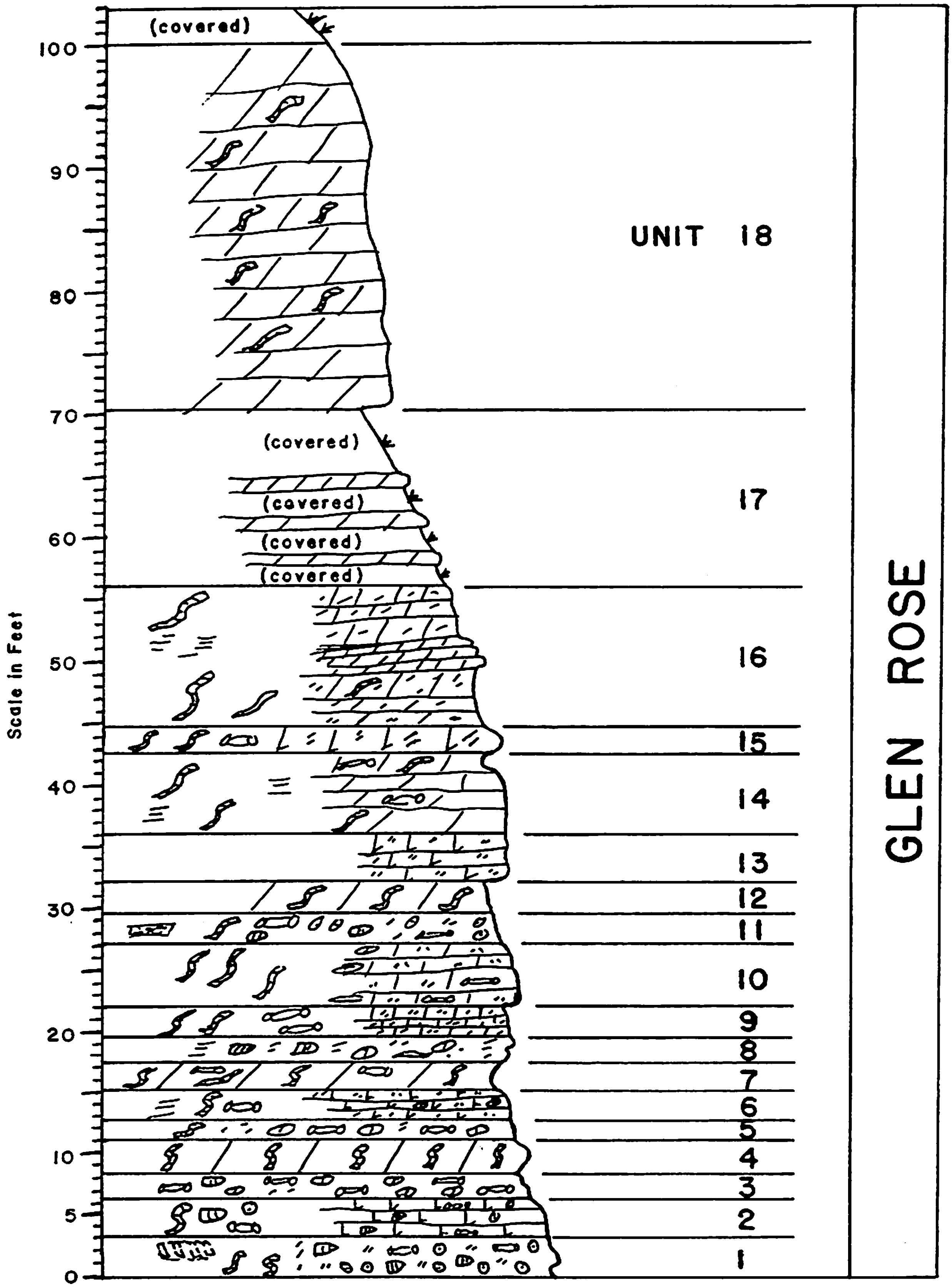


Cow Creek???

26.8	0.1	Massive talus can be seen on the left.
26.9	0.1	Spanish moss covers the Cypress trees of this area. Chara, a calcite depositing plant grows in the creek and can be seen when we cross the dam.
27.6	0.7	Turn right, cross dam, turn right again.
27.7	0.1	The cliffs on the left are of massive Cow Creek nodulus limestone. Calcite deposits and travertine are evidence of secondary deposition. The water table is beneath the talus line.
27.8	0.1	Talus slope on left.
27.9	0.1	A road dam crosses the creek. Continue straight ahead.
28.0	0.1	On the left is a slip-off slope of alluvium.
28.5	0.5	On the left are cliffs made up of Cow Creek limestone. At the contact between the top massive limestone and talus slopes are found a number of small caves caused by ground water erosion at the intersections of vertical joints and horizontal planes. Evidence of bats have been found in some of the caves. Travertine and botryoidal are also found.
28.7	0.2	At exit gate turn right and cross dam.
28.8	0.1	Bear left-up hill.
29.1	0.3	Drive through entrance gate to Cypress Lake Gardens.
29.3	0.2	Turn left.
29.4	0.1	The house located on the left is 135 years old.



29.5	0.1	<u>Stop 1.</u> Park as directed by coolies. Refer to Rebecca Spring page 36A. Return to cars--allow cars on side road to proceed first.
29.8	0.3	Turn left and cross cattleguard.
30.6	0.8	Cross cattleguard #2 and bear left.
30.7	0.1	The road built across this man-made dam confines Turkey Creek Lake.
30.9	0.2	Turn right onto Turkey Canyon Drive. Glen Rose limestone is seen exposed on the ground.
31.2	0.3	Turn right onto Swing Horse Circle.
31.3	0.1	Turn right onto Lake Park Road. Proceed right downhill. Fossils can be found along the road which follows near the creek.


Scale in Feet
0
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10
20
30
40
50
60
70
80
90
100
(covered)
(covered)
(covered)
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UNIT 18
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15
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11
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2
1
GLEN ROSE

Location: Section starts at base of cliffs on the Zaccaria Ranch along the northeast side of Cibolo Creek approximately 0.3 miles north of where FM 1863 crosses the creek.

UNIT	THICK	DESCRIPTION
1	3.4'	Limestone: muddy, fossiliferous, coated-grain, intrasparite; contains poorly sorted, well rounded, fine to very coarse sand-size allochems; numerous miliolids and ostracods, tiny gastropod steinkerns, *Textularia* sp., *Globigerina* sp.; lower one-foot is burrowed extensively, upper one-foot is cross-bedded; nonporous; hard; thin to medium bedded; middle part nodular weathering; yellowish gray 5Y8/1 on fresh surface, weathers medium to dark gray.
2	3.0'	Dolomitic limestone: muddy, fossiliferous, coated-grain, intrasparite; contains poorly sorted, well rounded, fine to coarse sand-size, horizontally oriented allochems; numerous miliolids and gastropod steinkerns; moderate number of dolomitized burrow-fills; less than 5% porosity; bedding partially obscured by weathering, medium bedded; yellowish gray 5Y7/2 with light olive gray 5Y6/1 burrow-fills on fresh surface, weathers medium gray to black.
3	2.0'	Limestone: intraclastic miliolid biosparite; contains moderately sorted, well rounded, horizontally oriented, fine to coarse sand-size allochems; numerous miliolids with a few other types of foraminifera, mixed shell-fragments, few gastropods and ostracods; nonporous; hard; unit consists of two beds, each one-foot thick; yellowish gray 5Y8/1, weathering medium to dark gray.
4	2.6'	Dolomite: finely crystalline, saccaroidal; extensively burrowed; 10% to 15% porosity; moderately hard; massive - bedding obscure; mottled, grayish orange 10YR7/4 with light olive gray 5Y5/2 burrow-fills, weathering dark gray to black.

5	1.6'	Limestone: fossiliferous intrasparite; contains poorly sorted, well rounded, unoriented, fine to very coarse sand-size allochems (a few clasts are up to ½" in diameter); numerous miliolids and mixed shell-fragments; burrowed; nonporous; hard; medium bedded; yellowish gray 5Y8/1, weathering medium to dark gray.
6	2.6'	Dolomitic limestone: intraclastic shell-fragment biomicrite; contains approximately 25% fine to coarse sand-size, horizontally oriented allochems; few ostracods and miliolids; few burrows; a few indistinct thin laminae observed in slab; moderately hard to hard; approximately 5% porosity; medium bedded; yellowish gray 5Y8/1, weathering medium to dark gray.
7	2.3'	Dolomite: finely crystalline, saccaroidal; contains a few leached miliolids; burrowed, especially near base; 10% to 15% porosity; moderately hard; massive; mottled, grayish orange 10YR7/4 to yellowish gray 5Y7/2, weathering dark gray to black.
8	2.0'	Limestone; muddy, fossiliferous intrasparite; contains poorly sorted, rounded, fine to very coarse sand-size, horizontally oriented allochems; ostracods, oyster shell-fragments, numerous tiny gastropod steinkerns, pellets; approximately 5% porosity; very hard, resistant; blocky weathering profile, meium bedded; yellowish gray 5Y7/2, weathering dark gray.
9	2.6'	Limestone; mixed shell-fragment biomicrite; contains miliolids, ostracods; numerous burrow-fills; nonporous; hard; medium bedded; yellowish gray 5Y8/1, weathers dark gray.
10	5.0'	Dolomitic limestone: muddy, intraclastic miliolid biosparite; contains well-rounded and sorted, fine to coarse sand-size, unoriented allochems; ostracods and oyster shell-fragments; numerous partially dolomitized burrow-fills; nonporous; hard; medium bedded; yellowish gray

5Y8/1 with scattered yellowish brown iron-stained allochems and light olive gray 5Y6/1 burrow-fills.

11	2.0'	Limestone: muddy, fossiliferous, coated-grain intrasparite; contains poorly sorted, rounded, medium to very coarse sand-size, oriented allochems; miliolids, a few ostracods and small gastropod steinkerns; cross-bedding visible in to slab; scattered dolomitized burrow-fills; non-porous; moderately hard; medium bedded; unit is not well exposed, but is highly weathered and leached; grayish orange 10YR7/4 to moderate yellowish brown 10YR5/4, allochems are stained orange brown, weathers to medium to dark gray.
12	3.0'	Dolomite: finely crystalline, saccaroidal; burrowed; 10% to 15% porosity; moderately soft to moderately hard; massive; unit isn't well exposed; light olive gray 5Y6/1, weathering dark gray to black.
13	4.0'	Dolomite limestone: mixed shell-fragment biomicrite; less than 5% porosity; hard; medium bedded; yellowish gray 5Y8/1 to 5Y7/2, weathers medium to dark gray.
14	6.7'	Dolomite: finely crystalline, saccaroidal; contains scattered leached miliolids; burrowed; wispy horizontal laminae visible in slab; 10% to 15% porosity; yellowish brown iron stains around larger pores; moderately hard; bedding obscured by weathering; mottled, grayish orange 10YR7/4, yellowish gray 5Y7/2, light olive gray 5Y6/1, weathers dark gray to black.
15	1.5'	Dolomitic limestone: mixed shell-fragment biomicrite; contains fine to coarse sand-size allochems; miliolids; dolomitized burrow-fills; approximately 5% porosity; hard; massive; mottled, yellowish gray 5Y7/2, light olive gray 5Y6/1 burrow-fills, weathers medium to dark gray.

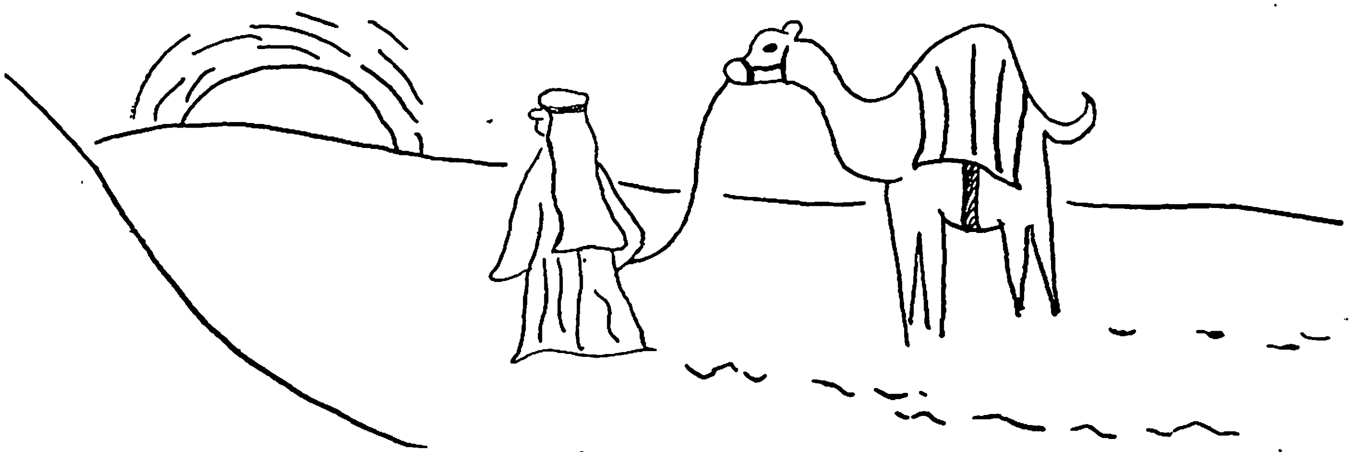
16	11.8'	Dolomite: finely crystalline, saccaroidal; contains leached oyster shell-fragments, <u>Exogyra</u> sp.; extensively burrowed; beds in middle of unit have numerous iron-stained, yellowish brown laminations and mottles; 15% to 20% porosity in some beds; moderately hard to hard; medium to thick bedded; mottled, yellowish gray 5Y7/2 to light olive gray 5Y6/1, weathers dark gray to black.
18	30.0'	Dolomite: fine to medium crystalline, sugary; burrowed; 15% to 20% porosity; moderately soft to moderately hard; locally friable; thick bedded (bedding obscured locally by weathering); mottled, grayish orange 10YR7/4 to light olive gray 5Y6/1, weathering dark gray to black.
	18.0'	Covered interval.

Top of Glen Rose Formation.

Newcomb, John H., Geology of the Bat Cave Quadrangle, Comal and Bexar Counties, Texas. (unpublished thesis) University of Texas at Austin, August 1971. pp. 88-92.

Afternoon trip retraces a portion of the morning trip.

		Return uphill on Lake Park Road.
31.6	0.3	Turn left onto Turkey Canyon Road.
32.0	0.4	Turn left onto Western Skies Road.
32.3	0.3	Cross man-made dam.
32.4	0.1	Cross cattleguard.
33.1	0.7	Stop 2. Park on right shoulder. Please use caution while walking in this area.
		Return to cars. Cross cattleguard and bear right.
33.5	0.4	Pass through brick entrance gate.
33.8	0.3	Bear right and cross dam. Continue on Park Road bearing right.
34.2	0.4	Turn right onto Rebecca Creek Road.
37.1	2.9	Intersection of Hwy. 281 and Rebecca Creek Road. Turn left onto Hwy. 281.



S.A.S.G.S. is a "Sedimental" journey...

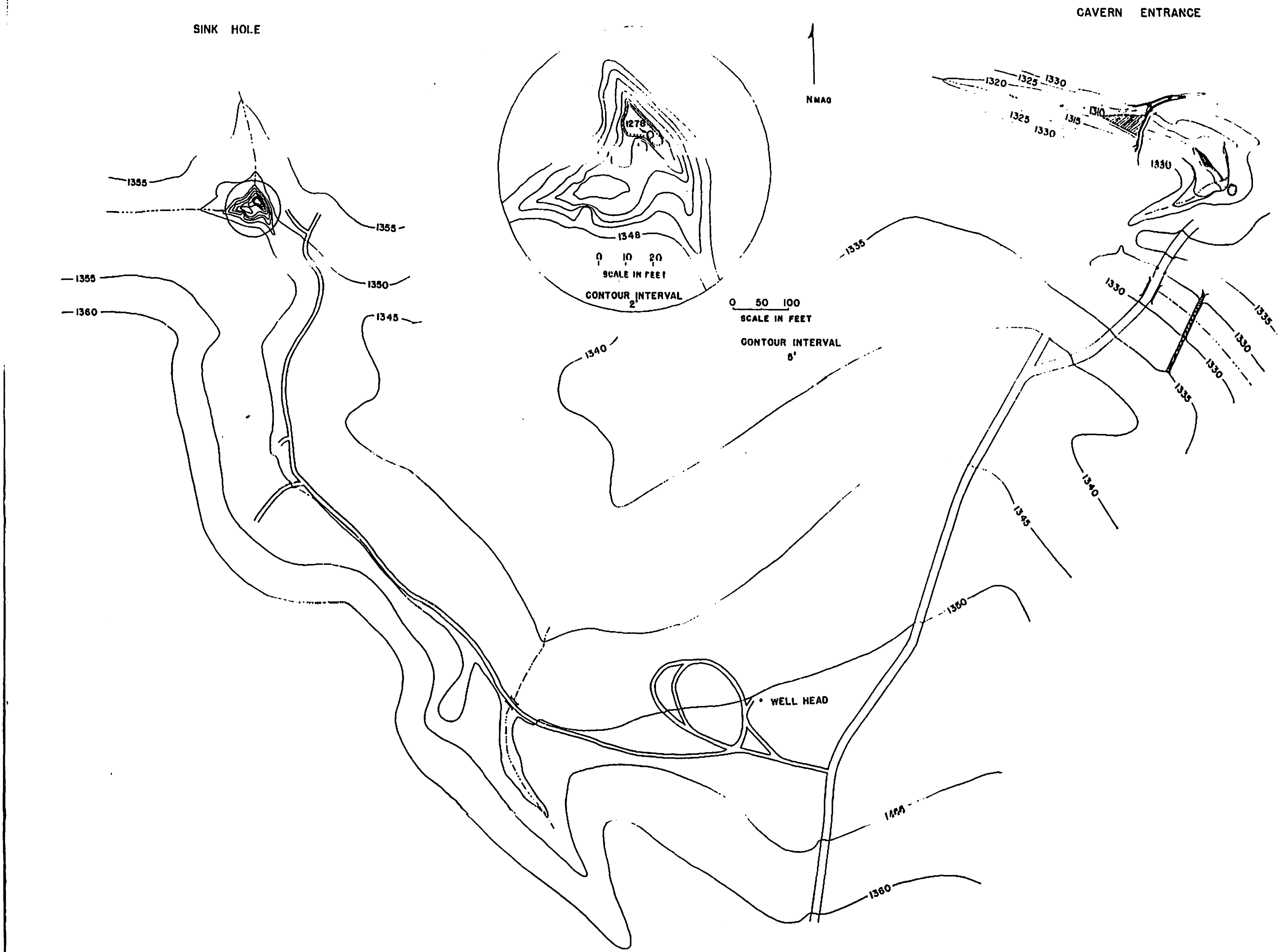
40.0	2.9	Town of Spring Branch. Continue on 281.
41.1	1.1	Hwy 281 divides.

41.6	0.5	Cross over Guadalupe River.
42.8	1.2	Divided highway ends.
45.5	2.7	Junction 46 and 281. Turn right onto 46.
46.1	0.6	The Lower Glen Rose formation is exposed in roadcuts along Hwy 46.
46.4	0.3	A small northeasterly trending adjustment fault crosses Hwy 46.
46.7	0.3	The Glen Rose limestone outcrop on the left side of the road has been strongly altered to a greyish clay. Fossils are very scarce in this spot.
47.2	0.5	Cross Lewis Creek, a tributary to Cibolo Creek.
47.6	0.4	Quarry located on the right.
48.3	0.7	Junction Hwy 46 and Bulverde Road. Continue on 46.
49.5	1.2	Road to Anhalt enters from the right. Continue on 46. Upper Glen Rose outcrops can be seen for the next three miles.
49.9	0.4	Lasewell Road enters from the left. Continue on 46.
50.9	1.0	St. Joseph's Catholic Church located on the left.
51.5	0.6	Tanks such as the one seen on the right are prevelant in this area and are used for watering livestock.
52.4	0.9	Blanco Road enters from the left. Continue on 46.
54.3	1.9	Evans Road enters from the right. Continue on 46.
55.1	0.8	Roadside rest area on left of road.

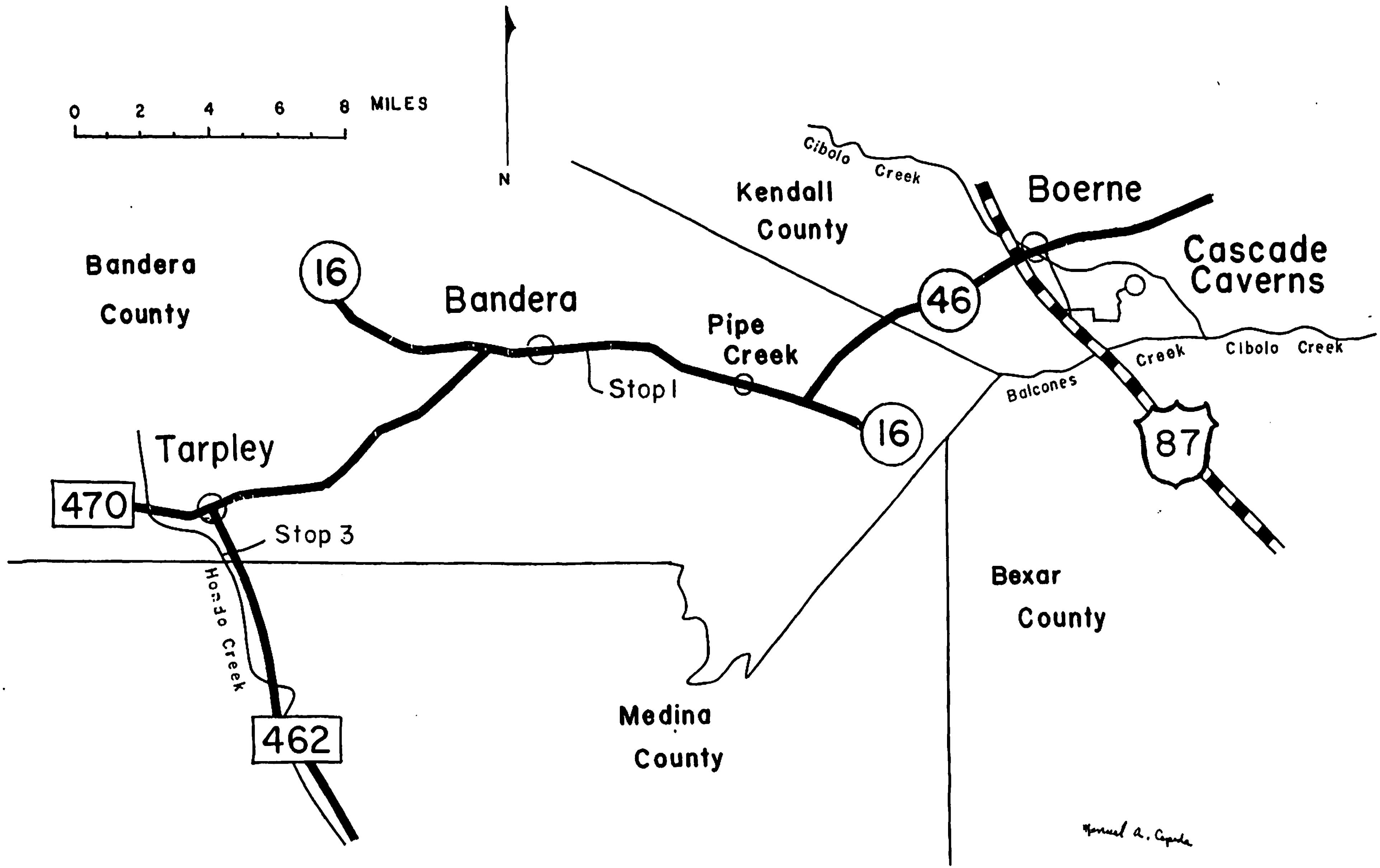
55.8	0.7	Bergheim. Continue on Hwy 46. Farm road 3160 leads to Kendalia and Edge Falls. We suggest you visit Edge Falls Uvala, a lovely unique area, but somewhat spoiled by negligence.
56.6	0.8	Upper Glen Rose roadcuts can be seen for the next three miles.
58.5	1.9	On the left is a polo field.
59.7	1.2	Alluvial valleys such as this are used for farmland because of the rich soil.
64.3	4.6	Kendall County Fairgrounds on the left.
65.0	0.7	Enter Boerne, Texas. Population 2432. Cibolo Creek is just to the left of the road.
65.4	0.4	The concrete dam on Cibolo Creek has created a recreational area for the residents of Boerne. This water is not used for any purposes other than recreation. All water for residential and cattle use is drawn from wells.
65.7	0.3	Junction of Hwy 87. Turn left onto 87. Cross over Cibolo Creek.
65.9	0.2	On the left is First Baptist Church of Boerne.
66.0	0.1	On the hill to the right is St. Peter's Catholic Church.
66.3	0.3	Highway 87 bears left.
67.2	0.9	Highway divides.
68.4	1.2	Exit at Scenic Loop Drive/Cascade Caverns Rd
68.7	0.3	Turn left, go under overpass.
68.8	0.1	Turn left.

69.0	0.2	Turn right onto Cascade Caverns Road.
69.1	0.1	Take right fork and follow Cavern road.
70.4	1.3	Bear left for entrance to Cascade Caverns.
70.7	0.3	Cross cattleguard.
70.8	0.1	Take left fork.
70.9	0.1	Cross cattleguard #2.
71.1	0.2	Cross cattleguard #3.
71.4	0.3	Arch, Cascade Caverns Entrance.
71.6	0.2	Turn left for entrance to campgrounds.

Er... Maybe we were a bit hasty in promising HOT SHOWERS.



SINK HOLE
CAVERN ENTRANCE
NMAG
1278
1348
0 10 20
SCALE IN FEET
CONTOUR INTERVAL
2'
0 50 100
SCALE IN FEET
CONTOUR INTERVAL
5'
1355
1350
1345
1340
1335
1330
1325
1320
1315
1310
1360
WELL HEAD



APRIL 8, OPTIONAL FIELD TRIP

SUNDAY ROAD LOG
Glen Rose Fossils and Dinosaur Tracks

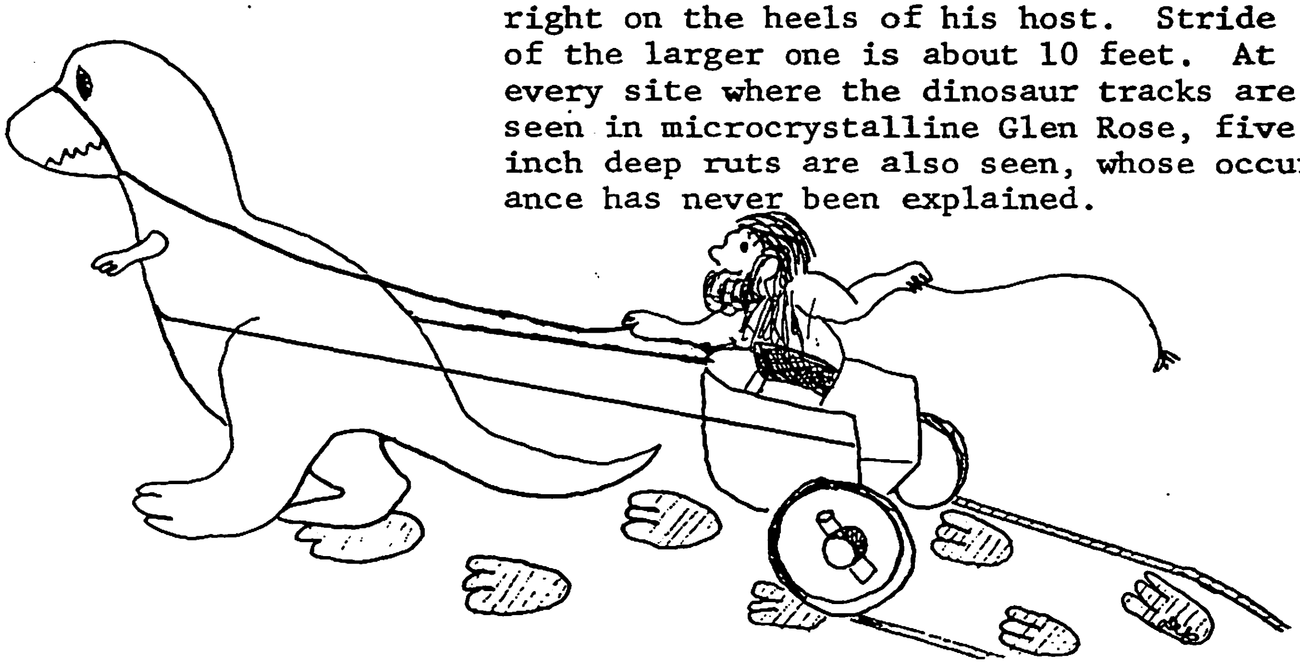
Cumulative Mileage	Interval Mileage	
0.0	0.0	Parking lot at Cascade Caverns.
0.2	0.2	Arch entrance to Cascade Caverns.
0.4	0.2	Cross cattleguard.
0.7	0.3	Cross cattleguard #2.
0.9	0.2	Cross cattleguard #3.
1.1	0.2	Road enters from left, continue ahead.
1.9	0.8	Sharp left turn.
2.7	0.8	Stop sign, bear left.
2.8	0.1	Stop sign, turn right onto access road.
2.9	0.1	Turn left and enter Interstate 10 W.
7.9	5.0	Take Hwy 46 Exit to access road.
8.1	0.2	Stop sign, turn left onto Hwy 46.
19.1	11.0	Stop sign, Junction Hwy 16 and 46. Turn right onto Hwy 16.
29.1	10.0	<u>Stop 1</u>. Park cars on right side of road. Glen Rose fossils are abundant at this site. The elevation of the roadcut is 1260 feet above mean sea level, and 60 feet above the bed of Bandera Creek. This eroded shelf is in the lower Glen Rose, representing a time when the water was deeper than at the time of the dinosaur tracks and the evaporite members which characterize some of the upper Glen Rose.

Fossils found here include:
Hemiaster texana
Protocardium
Salenia texana
Tylostoma
Porocystis
Exogyra texana
Turritella
Loriolia
Nerinea
Pteria

Return to cars and proceed west on Hwy 16.

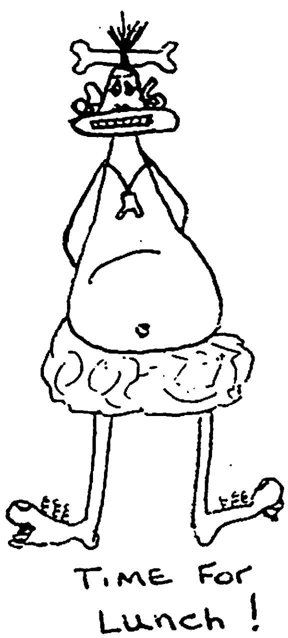
30.6	1.5	Stop light in Bandera. Junction Hwy 16 and 173. Turn right onto Hwy 16.
34.3	3.7	Junction FM 470 and Hwy 16. Turn left onto 470.
46.3	12.0	Junction FM 470 and 462. Turn left onto 462.
48.3	2.0	Stop 2. Park on shoulder of road.

The tracks here much resemble the tracks seen at the type site near Paluxy, Texas. (Thee Guidebook, Baylor Geological Society, S.A.S.G.S., April 1970, p. 51.) They vary from the heavy footpads of the Pleurocoelus to the ostrich-sized tracks of the scrap collector that followed in his wake. In some instances, the scavenger is obviously right on the heels of his host. Stride of the larger one is about 10 feet. At every site where the dinosaur tracks are seen in microcrystalline Glen Rose, five inch deep ruts are also seen, whose occurance has never been explained.



Several small springs and seeps on the creek bank adjacent to the road culvert feed into Hondo Creek. New limestone is being deposited as a lacework of small travertine dams on the ancient limestone blocks. Further up the stream are polluted seeps, easily identified by the abnormal heavy growth of algae and bacterial mold slime on the rocks. Fecal pollution, high in nitrogen compounds, coming from barn yards, feed lots, and rural septic tanks, follows joint patterns for considerable distances and penetrates into the Edwards aquifer. The major portion of the water you see here will enter directly into the Edwards as it crosses the fault recharge zone. Approximately 60 feet downstream may be found a Glen Rose caprinid bioherm on the right side of the creek. A fault line crossing the stream, striking north-south, can be seen. The many joint patterns in the rock ledge above the exposed reef bed are also observable. Several dozen cliff swallow nests (Petrochelidon pyrrhonota) are glued to the concrete beams of the road bridge that crosses this stream just northwest of the stop point. These birds are also associated with karst areas and use cave entrances and other protected locations.

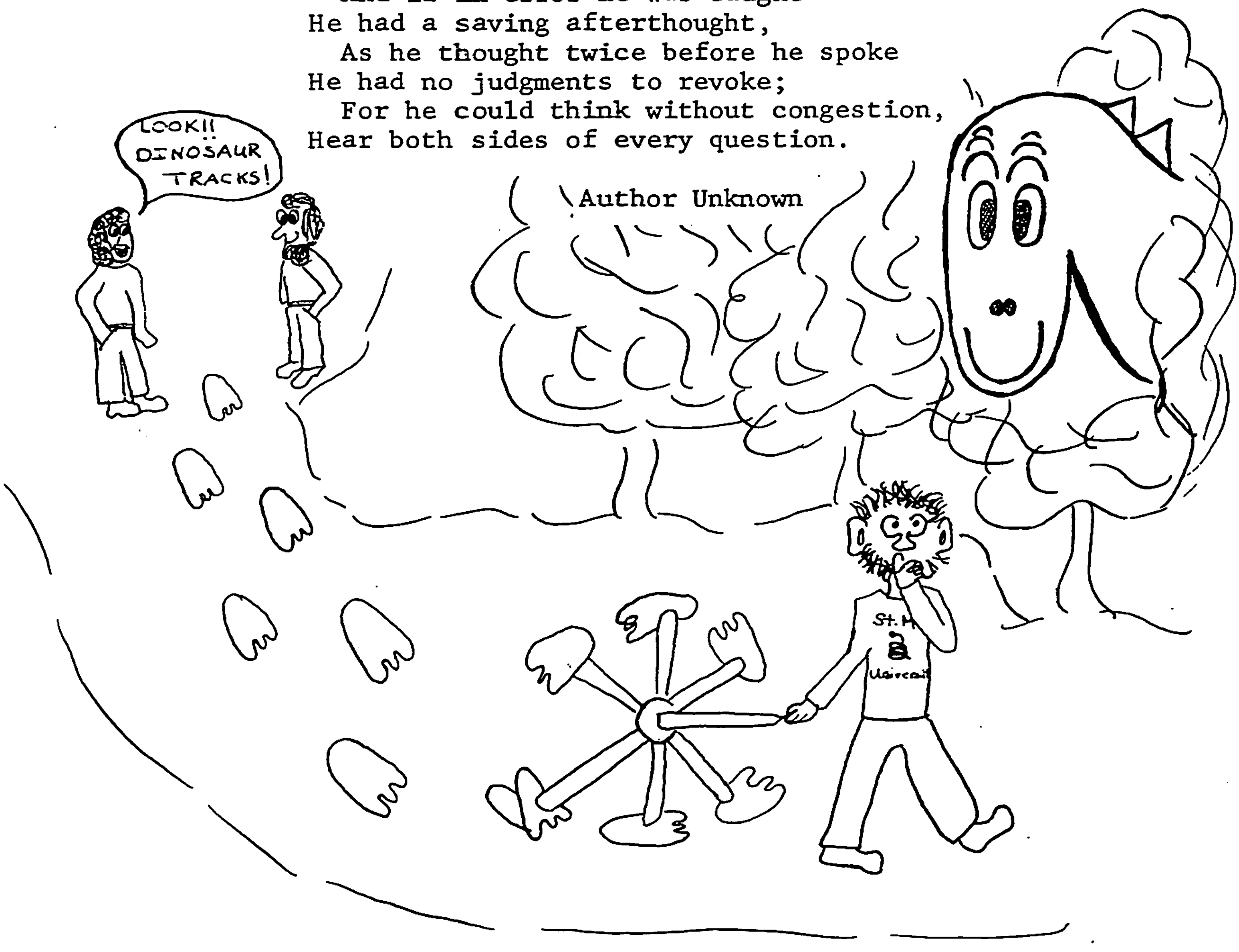
End of trip. Please drive carefully.



THE DINOSAUR

Behold the mighty dinosaur
  Famous in prehistoric lore,
Not only for his weight and strength
  But for his intellectual length.
You will observe of these remains
  The creature had two sets of brains-
One in his head (the usual place),
  The other at his spinal base.
Thus he could reason 'A priori'
  As well as 'Aposteriori'.
No problem bothered him a bit:
  He made both head and tail of it.
So wise he was, so wise and solemn
  Each thought filled just a spinal column.
If one brain found the pressure strong
  It passed a few ideas along;
If something slipped his forward mind
  And if in error he was caught
He had a saving afterthought,
  As he thought twice before he spoke
He had no judgments to revoke;
  For he could think without congestion,
Hear both sides of every question.

Author Unknown



CAVERNS OF SONORA
ROAD LOG

This is an optional tour with no guide from St. Mary's.

Cumulative Mileage	Interval Mileage	
0.0	0.0	Parking lot at Cascade Caverns.
0.2	0.2	Arch entrance to Cascade Caverns.
0.4	0.2	Cross cattleguard.
0.7	0.3	Cross cattleguard # 2.
0.9	0.2	Cross cattleguard # 3.
1.1	0.2	Road enters from left, continue ahead.
1.9	0.8	Sharp left turn.
2.7	0.8	Stop sign, bear left.
2.8	0.1	Stop sign, turn right onto access road.
2.9	0.1	Turn left and enter Interstate 10 W.

Take Sonora Caverns exit from Interstate 10, 9 miles west of Sonora. Turn left onto FM. 1989.

	5.8	Turn left off FM. 1989 onto Sonora Caverns Road.
	1.6	Sonora Caverns. Refer to "Caverns of Sonora" on page 93A in the appendix for additional information.

APPENDIX

HISTORY OF NEW BRAUNFELS

Deborah St. Clair

The city of New Braunfels was founded on Good Friday, March 21, 1845, by German immigrants led by Prince Carl of Solms-Braunfels. Situated on the Guadalupe and Comal Rivers, it was named for the city of Braunfels on the Lahn river in Germany.

The earlier inhabitants had been Karankawa, Lipan, Tonkawa, and Waco Indians. In the 1840's cannibalism thrived among the Tonkawas. Their women ate the flesh of the Waco Indians in the hopes that their sons would inherit bravery.

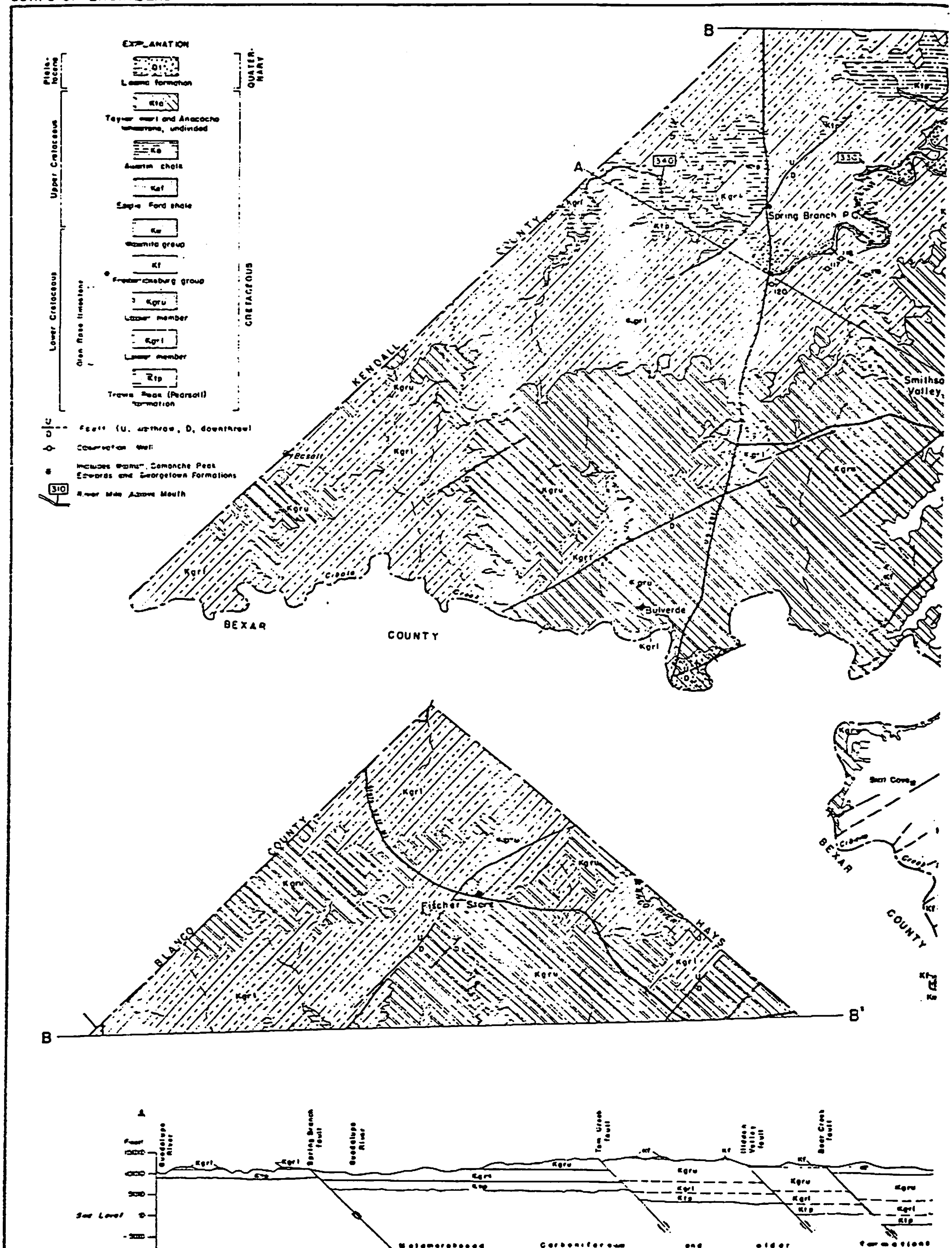
The German settlers bought 1,265 acres of land from Rafael L. Garza and his wife Maria Antonia Veramendi Garza. In 1845 the Colonists drew for lots. The city was incorporated on May 11, 1846 but the Texas legislature did not ratify the charter until 1847. By 1850 it had become one of Texas' largest and most important cities.

Among the early craftsmen were bankers, cabinetmakers, carpenters, coppersmiths, locksmiths, machinists, tinsmiths, turners, saddlers, tailors, shoemakers, and wagonmakers. The first industries were brick kilns, cotton gins, door and blind factories, flour and grist mills, breweries, sawmill, soap and candle house, and a woolen mill. The beginnings of these industries were greatly facilitated by the two rivers and the springs. Another industry was the manufacture of saltpetre from bat guano in the caves for ammunition during the civil war. Two of the very first industries were the flour and grist mills, founded by William H. Merriwether from Tennessee and John Torrey from Galveston, Texas. They are now incorporated into the H. Dittlinger Roller Mills Company, a division of the Flour Mills of America.

One of the biggest events of the year in New Braunfels is the Wurstfest held the last week of October. Since the first Wurstfest in 1961, held on proclamation by the mayor, it has grown from a small local festival celebrating sausage to an internationally-known celebration. In fact the city of Braunfel, Germany sent emissaries to the Wurstfest in 1964 as a result of an invitation extended to them by a young travel consultant with the KLM-Royal Dutch Airlines. In 1971 the 11th annual Wurstfest attracted 125,000 people who consumed 39 tons of wurst and 37,000 gallons of "New Braunfels Ice Water" (Beer) with which St. Mary's students are well acquainted.

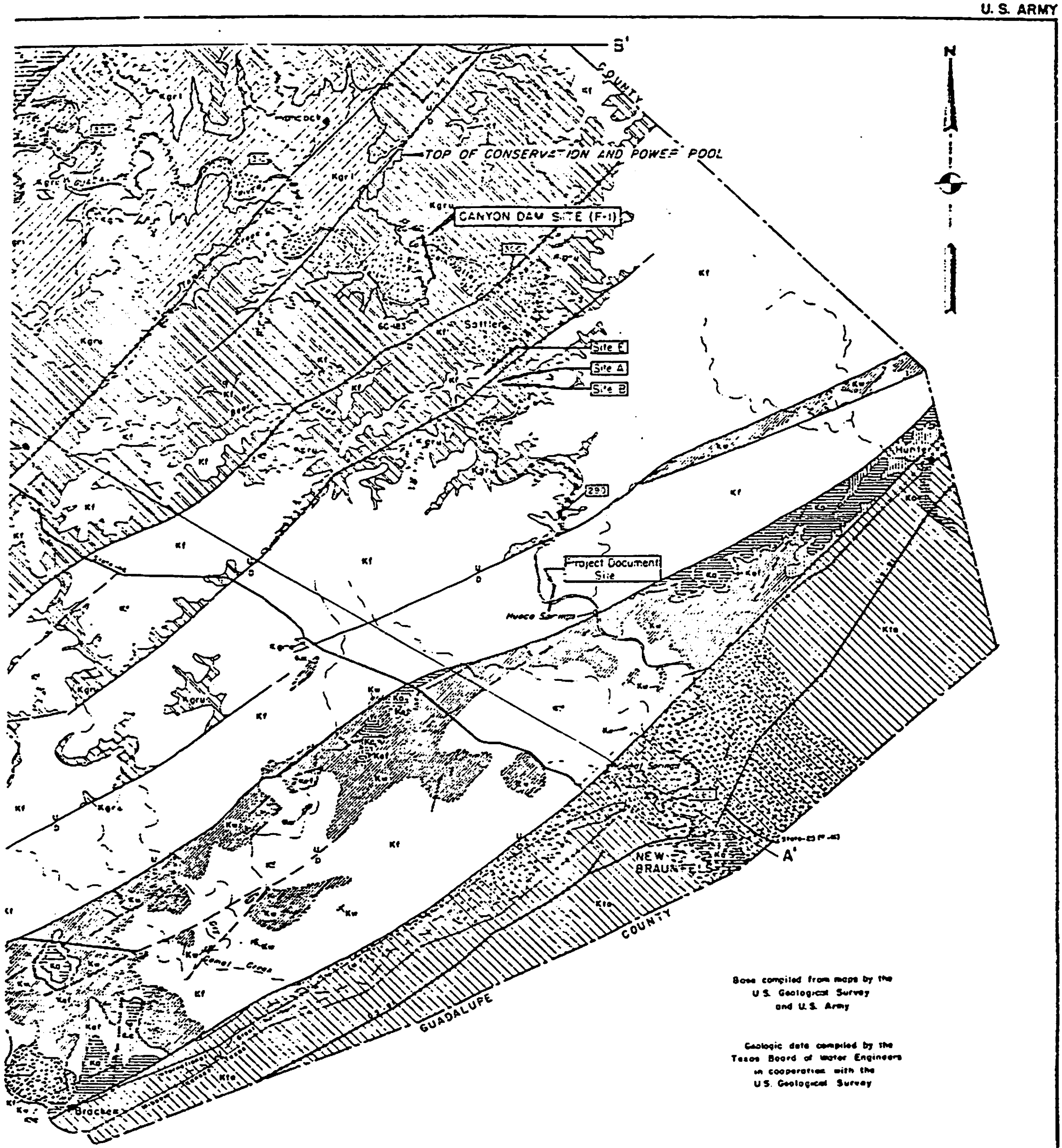
References

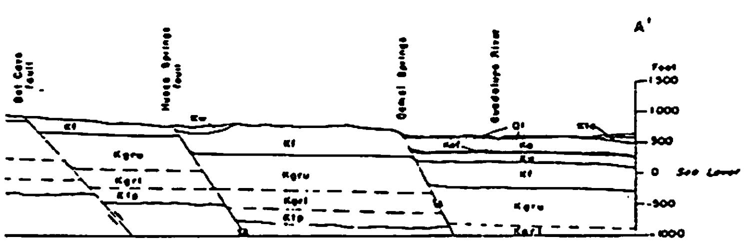
Pamphlets from New Braunfels



PROFILE AND GEOLOGIC SECTION ALONG LINE A-A'

U. S. ARMY





GUADALUPE RIVER BASIN, TEXAS

CANYON RESERVOIR

GUADALUPE RIVER, TEXAS

AREAL GEOLOGY

COMAL COUNTY, TEXAS

SCALE OF MILES

TO ACCOMPANY 1962 G.S.A. FIELD TRIP GUIDE BOOK

FIELD TRIP NO 12 — INSPECTION OF FOUNDATION AND CONSTRUCTION, CANYON DAM PROJECT, CORPS OF ENGINEERS, FORT WORTH DISTRICT

GEOLOGY OF COMAL COUNTY

Randolph Eisele and Bill Gray

Sedimentary rocks may be seen at the surface in all parts of Comal County. Small outcrops of igneous rocks occur near the Kendall County line, and metamorphic rock occurs in the log of the oil test (well F32) on the E. J. Heidrick ranch 6½ miles west of New Braunfels.

The sedimentary rocks are composed of layers of limestone, shale, clay, sandstone, and sand of Cretaceous age. The limestones, sandstones, and sands contain the underground water reservoirs in Comal County. Openings in rocks such as cavities in limestone caused by solution or fractures or spaces between grains of sand, permit the movement of water from the surface downward to the ground water reservoirs and also laterally within the reservoirs. Clays and shales generally transmit little or no water and are regarded as barriers which retard or prevent the movement of water.

The occurrence of ground water is closely related to the geologic history of Comal County. Gradual elevation of the land relative to the level of the sea is clearly shown by the upward succession of strata marked by the fossil remains of animals contained in them. Breaks in the continuity of sediments that were deposited in the sea are indicated by the absence of strata that are known to occur elsewhere in Texas.

More abrupt movements within the earth underlying Comal County have resulted in the dislocation of the rock, so that in some places formations that were deposited early in the geologic history are now found to be in contact with and at the same level as formations that were deposited much later and normally being at much higher levels.

Structural Geology of Comal County

In Comal County, the development of ground water reservoirs—particularly reservoirs in the Edwards, Comanche Peak, and Glen Rose limestone—and the position of the main channels of movement of ground water are closely related to a system of faults in the Balcones fault zone. This zone is 20 miles wide in places and extends from near Waco southwest through Comal, Bexar, and Medina Counties into Uvalde County. The faults are roughly parallel, and in Comal ranging from S 45° W to S 60° W. In general, the hades of the faults are steep. In many places the traces of the faults form nearly straight lines in fairly rough topography indicating that the hade may be nearly vertical. Clinometer measurements at a few places along the Comal Springs fault show that the hade ranges from 20 to 30 degrees from the vertical.

Comal Springs Fault

The most conspicuous fault in the zone forms the escarpment separating the Coastal Plain from the Edwards Plateau, and is here designated the Comal Springs fault. The fault enters the eastern part of Comal County near Hunter, passes through Landa Park at New Braunfels, and continues westward through Bracken near the southwestern extremity of Comal County. Comal Springs issue from fissures along this fault. At some places along the fault the Taylor marl is brought in contact with the Edwards limestone, indicating the possibility of a stratigraphic displacement of 400 to 600 feet. North of this fault, water in the Edwards limestone occurs under unconfined conditions and is of good chemical quality. South of the fault the Edwards is buried to a depth of several hundred feet; the water in it is under artesian pressure and is highly mineralized.

Age of Faulting

The age of the faulting along the Balcones fault zone has not been accurately determined, but it is believed that faulting may have occurred from Early Cretaceous to Recent geologic time. Varying opinions exist, but evidence has been presented to show that there have been three movements along the Balcones fault zone at Waco, Texas, the first during Early Cretaceous time, the second during Georgetown time, and the third during very recent time. The Comal Springs fault extends the length of Comal County, through New Braunfels, causing a bold escarpment with an extremely youthful appearance. The escarpment seems to have been only slightly eroded as though it might have been formed very recently. This appearance may be deceptive, however, as much of the Edwards limestone has been removed internally by solution of infiltrating waters instead of by external erosion. However, rapids are found in the Guadalupe River at nearly every place that a fault crosses the river.

Cause of Faulting

Individual faults in the Balcones fault zone seem to be definitely related to each other in origin because of their roughly parallel pattern. Most of them are normal faults with downthrow to the southeast. Uplift occurred along the thousand-mile fault zone with compensatory sinking of the coastal plain, underlain with Cenozoic rocks.

Regional Dip

The regional dip of the Cretaceous rock on the Edwards Plateau is generally accepted to be about 15 feet to the mile in a southeasterly direction. In the Coastal Plain the dip of the subsurface Cretaceous steepens considerably. In Comal County, however, as a result of crustal deformation, there are many departures from the regional dip. In the vicinity of faults, the dips are likely to be abnormally steep. There has been an observed perceptible northwest dip in the Austin chalk and Taylor marl on the Guadalupe River about 2 miles south of the Comal Springs fault. In addition to these local irregularities, in the eastern part of Comal County there is a rather general steepening of the rocks eastward.

Reference

George, W. O. and S. D. Breeden and W. W. Hastings, Geology and Water Resources of Comal County, U. S. G. S. Water Supply Papers. Bulletin 1138, 1952.

COMAL SPRINGS

Randy Eisele and Bill Gray

Groundwater Discharge

Comal Springs have the largest average discharge of any known springs in the southwestern part of the United States. The average flow during the 19 year period of 1928-46 was 324 second-feet (cubic feet per second) or about 210,000,000 gallons per day. This is equivalent to 640 acre-feet per day or 235,000 acre-feet per year. It is greater than the average surface runoff from the 1,423 square miles drained by the Guadalupe River above the Spring Branch gauging station during the same period. The dissolved solids in the water at the springs average about 285 parts per million. On the basis of average flow, an average of more than 200 tons of rock material is carried away daily in solutions by the water that issues from these springs. The discharge of the springs is better sustained than that of any other of the large springs of the Balcones fault zone. The minimum, maximum, and average recorded discharge of the fault zone, including Comal Springs, together with the ratio of the minimum discharge to the maximum and average discharge are given in table A on next page.

TABLE A

Comparison of the minimum, maximum and average discharge of Comal Springs and other important springs of the Balcones Fault Zone:

SPRINGS	MINIMUM	MAXIMUM	AVERAGE
Comal at New Braunfels	245	420	324
San Marcos at San Marcos	51	286	153
Barton at Austin	12	139	41
Las Moras near Brackettville	5.8	60	76
San Felipe at Del Rio	41	150	76
Goodenough near Comstock	96	700	179

The water from Comal Springs issues crystal clear at a temperature of about 74°F. from the foot of the escarpment formed by the Comal Springs fault. The water has been observed after relatively long dry periods and after heavy rains, in winter and in summer, and no trace of turbidity has been detected. The maximum observed variation in temperature is not more than a degree.

The water rises from a large number of openings in the Edwards limestone along a distance of 500 yards at the base of the Comal Springs fault escarpment. There is no spectacular rush of water, no discharge of gas with the water, and no travertine deposits in the vicinity of the springs. The

Springs supply nearly all of the water that flows in the Comal River which joins the Guadalupe River at a point about one mile east of the springs and at a level about 40 feet below the level of the springs.

The facts presented in this report suggest that Comal Springs are a point of discharge for an immense groundwater reservoir which also supplies wells and springs in the San Antonio area, and that the discharge of the springs varies with the volume of water in the reservoir. The large size of the reservoir is indicated by the remarkable constant rate of discharge of the springs, by the uniform temperature and the lack of turbidity of the water, and by the relation among fluctuation in discharge, rainfall, and rise and fall in water levels and wells. The geological information together with the runoff and seepage data available seems to justify the conclusion that a relatively large part of the discharge of Comal Springs comes from sources outside Comal County and beyond the adjacent parts of Bexar and Kendall Counties drained by Cibolo Creek.

The water is not coming from the north, because the intake transmission facilities are unfavorable in that direction; it is not coming from the east, because the hydraulic gradient shown by the altitude of the water level in wells is eastward from the springs; it is not coming from the south, because it is shut off by the Comal Springs fault as indicated by the difference in the chemical character of the water on the two sides of the fault. Therefore, it must be coming from the west and southwest. A major part of it must be coming from areas beyond the drainage basin of Cibolo Creek.

Movement of Groundwater

Groundwater may be classified in regard to its origin as connate water or meteoric water. The water trapped in sediments at the time of their deposition is called connate water. This water may be a brine similar to present sea water, or even more concentrated. After the formation has been exposed to the surface, or lifted above sea level, the sea water may be gradually flushed out and replaced by water from rain or snow and only such minerals as may be dissolved from the rock in the process of circulation will be found in the water. For example, the Edwards limestone yields potable water to Comal Springs, but contains salt water, petroleum, and gas in the oil fields of Caldwell County. Intermediate between these two kinds of water is that of poor quality found in areas where the circulation of meteoric water is comparatively slow as a result of structural features or because of clay or shale beds between beds of limestone. South of the Comal Springs fault a number of wells have been drilled into the Edwards limestone but have been abandoned because the water is too highly mineralized or has a hydrogen sulfide odor. This is strong evidence that there is very little circulation of water in the Edwards south of the Comal Springs fault.

Rate of Movement

The lack of turbidity in the water that issues from Comal Springs suggests that the water moves slowly underground and that a part of its course is through an intricate network of small openings that retard the velocity of the water to the extent that sediments are not carried along as in open streams. Locally however, at some distance from the springs, constricted openings may cause turbulent flow. The temperature of the springs are recorded at New Braunfels at 74°F. This suggests that the paths of circulation within the reservoir may reach depths of 300 to 500 feet below the surface at no great distance from the spring.

Cores obtained from an observation well near Comal Springs and on the upthrown side of the fault, show that the Glen Rose limestone is vuggy at a depth of 320 feet. The presence of solutional cavities at 320 feet is not proof that water is circulating at this depth at the present time.

The apparent lag in the increase in discharge of Comal Springs following heavy rains and rises in water levels does not mean that the water actually moves from the vicinity of San Antonio to Comal Springs within the 1 or 2 month period indicated by the lag. Only the change in head due to added water in the intake area and in the reservoir itself is transmitted at this rate. The time required for the water that falls as rain on the intake area west of Comal County to reach Comal Springs would probably be expressed in years rather than in days or months. Much research has been directed toward the rate of movement of groundwater, and with considerable success where the character and permeability of the materials that form the groundwater reservoirs are fairly uniform. The methods are more generally applicable to sand and sandstone reservoirs because of the more nearly uniform character of such aquifers. The application of formulas for the determination of the permeability of the limestones in Comal County would be difficult not only because of the irregularities in the character of the openings in the limestones but because it is believed that the movement of the water may be under artesian conditions in other parts.

Direction of Movement

The general slope of the water table in the wells in the Edwards limestone in this area is from the southwest towards the northeast, although locally the gradients may not conform to this general direction. Relatively high water levels recorded for a few wells along the northwest side of the Hueco Springs fault show the impounding affect of the fault. From the general direction of the gradient it may be assumed that some water enters Comal County. The general direction of the movement of water probably varies but little from time to time. As indicated by contours on a map, the general slope of the pressure surface is southeastward but at the Comal County line the contours swing rather abruptly northward, indicating an eastward slope of the pressure surface. In this area the water appears to move out from under its confining bed and continues northeast under water-table conditions.

The fact that the chemical character of the water southeast of the Comal Springs fault is poor compared to the quality of the water that issues from Comal Springs is further proof that the main body of water flows along the north side of the fault under water-table conditions rather than on the downthrown side of the fault. This change in the direction of flow of the water in the Edwards was probably caused by structural uplift and transverse faulting in the vicinity of Bracken, modifications which may have formed a barrier directing the water from its normal course in the artesian area. Following the general direction of the slope in Comal County, the water appears to move from the vicinity of Bracken toward and beyond Comal Springs. In the vicinity of the springs the slope is toward the springs from the north, west, and south, indicating a cone of depression caused by the discharge of the spring.

In wells drawing from the Glen Rose limestone the altitude of the water levels indicate that the water table slopes eastward toward the outcrop of the Edwards. On the divide between Cibolo Creek and the Guadalupe River, wells in the Glen Rose show a pronounced irregularity in the altitude and slope of the water table. This is characteristic of the water table in limestones in which the solution channeling is poorly developed.

Surface Water Supplied by Comal Springs

A complete record of the flow of Comal River below Comal Springs is available and a partial record is available for the period of 1928-32 indicating the flow of Comal Springs during that time.

During the period of 1933-50, the average flow of the river was 332 second-feet. Of this, it is estimated that an average of 8 second-feet was surface water runoff, representing an annual runoff of 1.2 inches from the 94 square miles of drainage area above the station. The average rainfall at New Braunfels for the period of 1933-50 was 33.6 inches, which is 3 inches above normal for that area. Data shows that an abundant and dependable supply of water is furnished by Comal Springs and the Guadalupe River below Comal Springs, and that rather large supplies of surface water are available from other streams in the area, but that storage will be necessary if a large continuous supply of water is to be obtained from sources other than Comal Springs.

Reference

George, W. O. and S. D. Breeden and W. W. Hastings. Geology and Water Resources of Comal County, U. S. G. S. Water Supply Papers. Bulletin 1138, 1952.

"Nein gut wasser, Nein gut beer, ja?"

"GRAY'S FAULT"

Bill Gray

"Gray's Fault" (an extension of the Bat Cave Fault)

East of the Guadalupe River, this fault forms the south side of a downfaulted block or graben in which a narrow wedge of younger rocks appears between outcrops of Edwards limestone. The estimated amount of throw is about 55-60 feet. (Actually the graben may be a slump or valley sink produced by the collapse of a former cavern in the Edwards limestone, which lowered the younger rocks below the level of the Edwards limestone thus protecting the fallen block from erosion).

In the western part of the county where the faulting has brought the upper member of the Glen Rose limestone in contact with the Edwards limestone, the displacement is estimated to be about 300 feet.

The strike of Bat Cave Fault enters the eastern boundary of the county about 2 miles north of the Comal Springs Fault, crosses the Guadalupe River about 2 miles north of Hueco Springs, and crosses the western boundary of the county 5½ miles northwest of Bracken in the vicinity of Bat Cave.

The strike of the fault is approximately N 55° E and dips at an angle of 35° to the southeast.

Edwards Limestone

Here the Edwards lies conformably upon the Comanche Peak limestone. The thickness of the Edwards in Comal County has not been accurately determined but it probably ranges from 350-500 feet. The major outcrop area is in the southwestern part of the county. The Edwards is composed almost entirely of hard, massive limestones that are extensively honey-combed. The most distinguishing characteristic of the formation is the occurrence of flint nodules ranging in size from small pebbles to irregularly lenticular-shaped masses as much as a foot in diameter. (See "Flint Nodules" in Appendix.) Other characteristics found here are large calcite veins and speleothems. The Edwards reef and associated limestones are generally light grey, crystalline, coarse-grained, organic, nearly pure limestone, with much calcareous shell detritus.

Georgetown Limestone

The limestone members of the Georgetown are generally light grey, compact, somewhat nodular, and crystalline with a considerable intermixture of shell fragments and fossils.

The matrix is finely crystalline and generally somewhat argillaceous. The strata are thin-bedded, and alternate with marly strata. The microfossil Globigerina washitensis is often present. Echinoid spines are frequent.

The observed thickness of the Georgetown limestone in the outcrop area in Comal County is about 15 feet. The Georgetown appears to be conformable with the Grayson (Del Rio) shale above it. In many places there is an abundance of well-preserved brachiopods Kingena waconensis (Roemer) in the thin marly beds of the formation. In the lower beds the fossil Alectryonia, an oyster recognized by the zigzag pattern on the margin of the shell, is fairly abundant. In many places, however, it is difficult to distinguish the Georgetowm from the Edwards.

Grayson (Del Rio) Shale

Like the Georgetown limestone, the outcrops of the Grayson shale are confined to the belt between the Comal Springs fault and the Bat Cave Fault. The Grayson appears to be conformable on the Georgetown. In the outcrop area the Grayson shale is about 30 feet thick. In Comal County, the Grayson is predominately marl. It weathers to a buff color at the surface, but drill cuttings are usually blue.

Exogyra arietina, an oyster having a shell shaped like a ram's horn, is considered to be a marker for the Del Rio formation. The Grayson is probably the most impermeable formation in Comal County and many surface reservoirs or stock tanks are constructed in the outcrop area.

Buda Limestone

The Buda limestone is believed to lie conformably upon the Grayson shale but there are few good exposures of the contact between the two formations. The thickness of sections lying north and northwest of the Comal Springs Fault does not exceed 30 feet. In many places in the outcrop area low brushy or wooded ridges are covered by boulders of Buda limestone which extend onto the slopes of the underlying Grayson. This is due to that characteristic of the Grayson which when it becomes wet acts like plastic and small land-slides cause the overlying beds of the Buda to give way and break up into boulders. The greater part of the Buda lime-stone as observed in Comal County is hard and brittle and has a porcellaneous texture. Its color is gray, yellow, and red and in most places it is speckled with small spots of darker-colored rock reported to be oxidized glauconite. Some of the outcrops of the Buda are honey-combed but the formation is not known to yield to wells in Comal County.

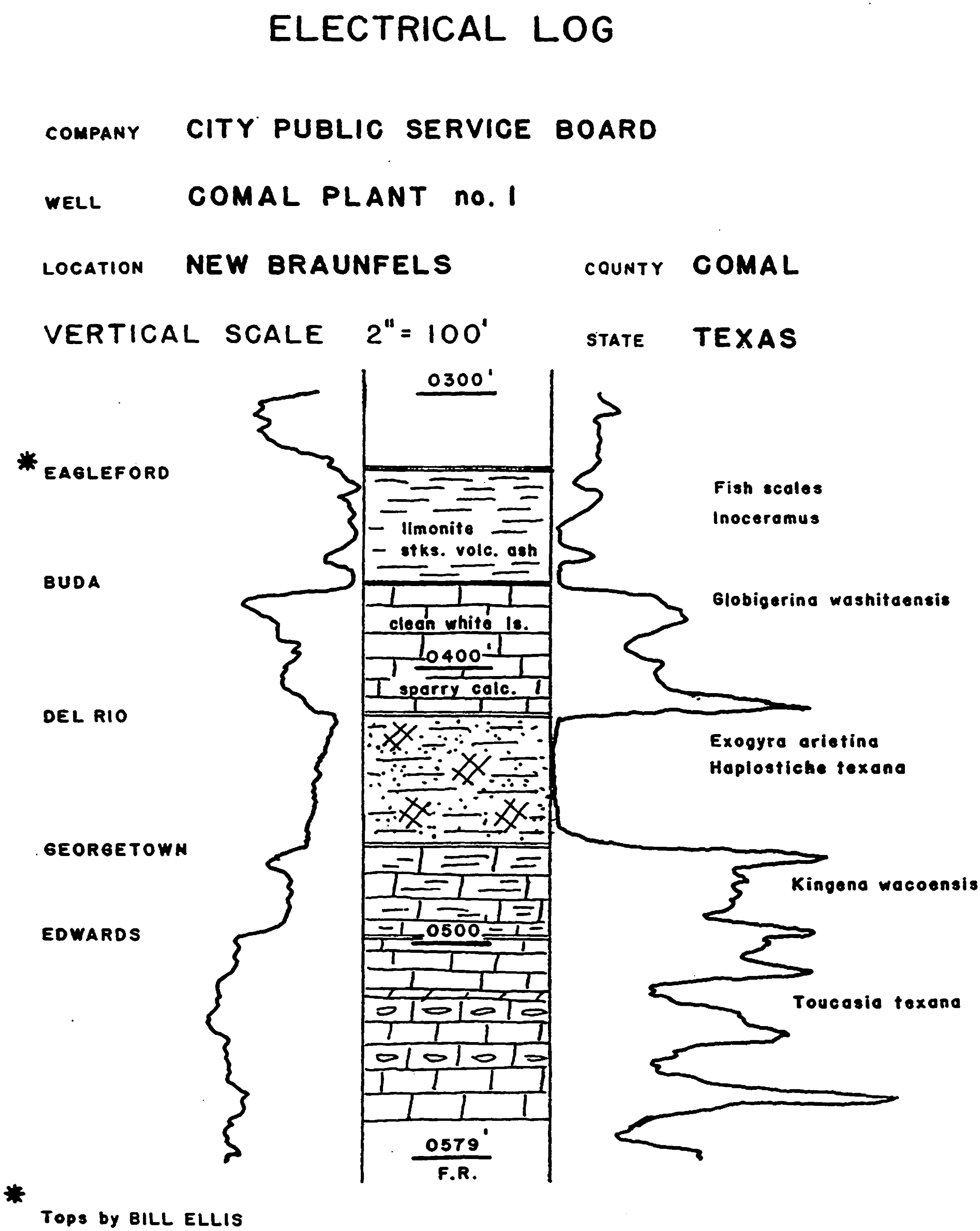
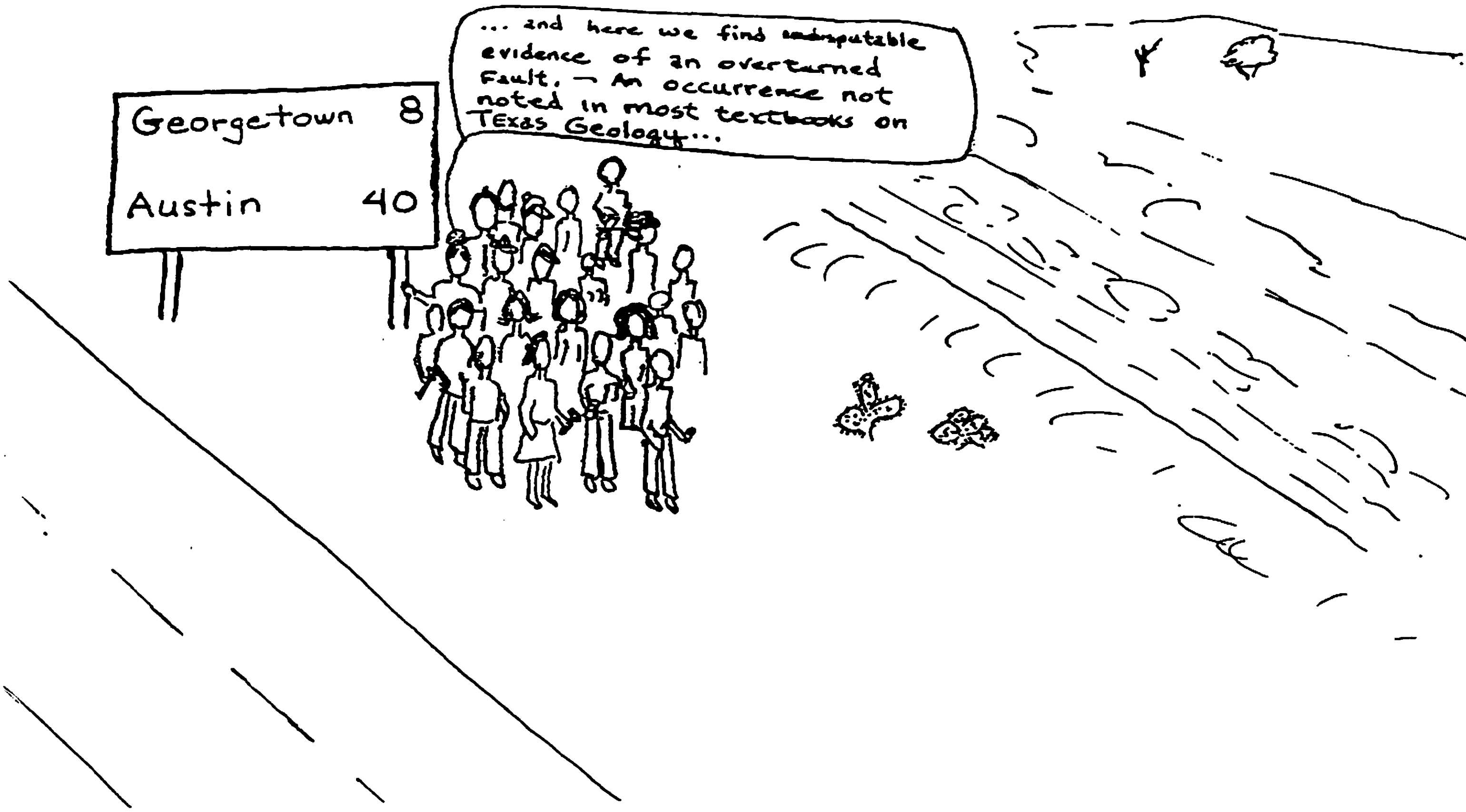

ELECTRICAL LOG
COMPANY CITY PUBLIC SERVICE BOARD
WELL COMAL PLANT no. 1
LOCATION NEW BRAUNFELS
COUNTY COMAL
VERTICAL SCALE 2" = 100'
STATE TEXAS
0300'
* EAGLEFORD
limonite
stks. volc. ash
Fish scales
Inoceramus
BUDA
clean white ls.
0400'
sparry calc.
Globigerina washitaensis
DEL RIO
Exogyra arietina
Haplostiche texana
GEORGETOWN
Kingena wacoensis
EDWARDS
0500
Toucasia texana
0579'
F.R.
* Tops by BILL ELLIS

Figure 1.

Reference

George, W. O. and S. D. Breeden and W. W. Hastings, Geology and Water Resources of Comal County, U. S. G. S. Water Supply Papers. Bulletin 1138, 1952.



BRACKEN BAT CAVE

Harcourt Newman and Jackie Black

Bracken Bat cave is located approximately ½ mile northwest of the Bat Cave Fault and 8/10 miles to the southwest of Natural Bridge Caverns. It is situated in the west central region of the Bat Quadrangle.

Access to the cave is gained from the bottom of a collapsed sinkhole. This cave is found in the lower unit of the Edwards Formation. The floor to ceiling measurement is approximately thirty feet, and the main passage trends for some 400 feet in the direction of N 23° W. The cave is generally developed along a system of joint patterns trending at a right angle to the Bat Cave Fault, which created a favorable environment for the solution of the existing rock structure.

Bat Population

As the name of this cave might imply, Bracken Bat Cave is most significant due to its large population of Mexican Free-tailed bats or guano bats (*Tadarida brasiliensis mexicana*). According to Dr. L. S. Adams, Bracken Bat Cave, in 1955, had the second largest bat population in the United States (largest was in Ney Cave, N.W. of Edge Falls in Bergheim, Texas). There is an estimated 40,000,000 population of the Free-tailed bat in Bracken Bat Cave. This figure is based on the rate of guano build-up. The population of the bat colony at Bracken changes with the season and reflects migration of the sexes as they move between the U.S. and Mexico. At times there are all males in the colony and at other times there are all females. Logically we might assume a mixed population at sometime, otherwise why 40,000,000 bats?

The free-tailed bat is a protected animal. Texas Legislature passed a law in 1917 making it a misdemeanor to willfully kill or injure any "winged quadruped known as the common bat." This legislation came as a result of a campaign by Dr. Charles A. R. Campbell of San Antonio who felt that bats were an economic asset.

Wartime use of bats ----Operation X-ray

Dr. L. S. Adams, a Pennsylvania surgeon, devised a plan to use bat-borne incendiary bombs against Japan during World War II. If dropped over Japanese industrial centers and storage depots the bats would seek shelter in inaccessible cracks and crevices and set off without warning a multitude of explosions and fires.[1] The idea appealed to President Roosevelt and military advisors and the project was approved.

After a great deal of research the free-tailed bat, Tadarida, was picked as the best for bomb carrying. This bat is found most extensively in Ney Cave and Bracken Cave. Removable screens were placed over the entrance to the caves to capture the bats. They were then transported to New Mexico and stored under refrigeration until a bomb and container could be designed. The bomb weighed only 1 ounce but was 3 times the weight of the bat. The containers were partitioned cylinders that would hold from 1,000 to 5,000 bats with bomb. Test drops proved that the containers would automatically open and release the bats which could then fly to a hiding place, chew off the bomb and leave. Everything was ready by 1944 but the project was suddenly cancelled. Apparently a much more deadly weapon was being developed which would later be used to devastate Hiroshima and Nagasaki.

Bats Pose Some Problems

Of more recent interest to the military, specifically the U.S. Air Force, are the dangers encountered by pilots flying through the area. Randolph Air Force Base located just a few miles south of Bracken Bat Cave has many high-performance jet aircraft which are no match for the tiny one-third ounce "Mighty Mouse." One bat, when ingested into a jet aircraft engine, can completely destroy the turbine vanes and "disable" the aircraft. Two bats could cause complete loss of power and consequently result in the death of the pilot and destruction of a million dollar aircraft. During October, 1967 there were 11 collisions with bats. The first reaction of the Air Force was most likely -- SEAL UP THE CAVE -- but upon due consideration they weighed the alternatives and contracted with the Smithsonian Institute, through the Air Force Office of Aerospace Research, USAF in Arlington, Virginia, to investigate the bats and recommend corrective action.

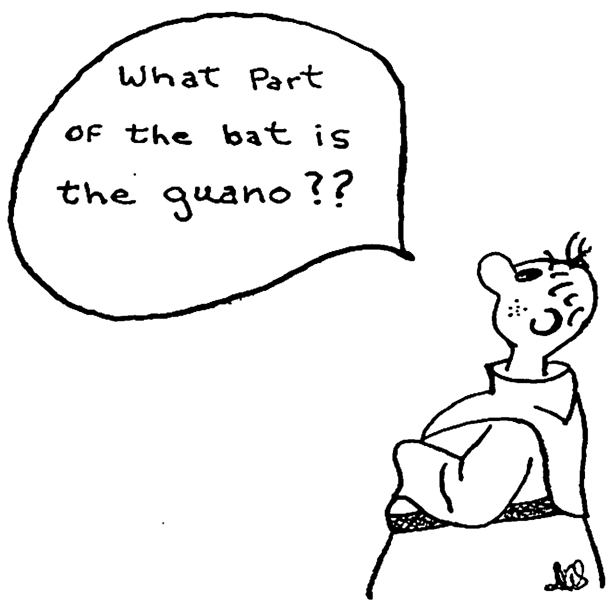
Through research, the investigating team estimated that the Bracken Bats consume more than ten tons (20,000 lbs) of insects in a single night. A series of letters were sent to authorities at Norwich University, Texas A & I University, Rockefeller University, University of Arizona, and the Woods Hole Oceanographic Institution. Their combined consensus of opinion was that the free-tailed bat should be left free. The Air Force (and other aircraft) should treat the area of Bracken Bat Cave as they would a mountain or other natural hazard and fly around it.

References

1. "Texas Bat Caves Served in Three Wars," The National Speleological Society, The Caves of Texas, April, 1948. 510 Star Building, Washington.

2. Williams, Timothy C. and Jante, M., The Smithsonian Institution Document AD 661329, April 1969, Defense Document Center Cameron Station, Alexandria, Virginia 22314.

3. Mohr, Charles E. and Sloane, Howard N. Celebrated American Caves. Rutgers University Press, New Brunswick, N.J., 1955.



NATURAL BRIDGE CAVERNS

Jackie Black

Natural Bridge Caverns is located southwest of New Braunfels near the southern edge of the Edwards Plateau. The deposits that form this area were laid down by shallow Cretaceous seas which advanced from the south and east to cover most of Texas. The marine limestone varies from chalky to massive facies reflecting different environmental conditions. The deposits of the cave area are made up of the Trinity and Fredericksburg Groups of the Lower Cretaceous Period.

The Glen Rose formation of the Trinity Group underlies the Fredericksburg Group and consists of calcareous beds of alternating hard and marly limestone. The Glen Rose shows several distinct layers in the cave. The bottom layers consist of broken soft strata, the middle is of thick solid limestone, and the top of shale and clay. This would indicate that deposition occurred in shallow seas. Two water tables are found in the Glen Rose--one between 130-175 feet and the second 240 feet below the top of the formation.

Many facies occur within the Fredericksburg Group and appear in several locations throughout the state but with no apparent regularity. Corresponding to the conditions of deposition, the Edwards formation forms a massive resistant nature. Flint nodules (see "Flint Nodules" in Appendix) and seams or evidence of rudistids throughout the limestone identify it in some areas. In other areas the Edwards is nearly pure calcium carbonate (produced by intraformational solution and redeposition) from which much of the lime has been dissolved, leaving a "honey-combed" appearance. The Edwards limestone is white and weathers grey when exposed to surface air.

Natural Bridge Caverns began its formation after the Cretaceous seas receded and the general area was uplifted well within the Cenozoic Era. Surface water charged with carbon dioxide percolated downward as groundwater through joints and bedding planes, dissolving calcium carbonate from the limestone and leaving small cavities within the rock. Continuous solution of this type resulted in the formation of pockets and the joining of cavities. Collapse occurred when the cavities reached a width too great for the overlying rock to support, thus creating larger cavities. Continual solution and resulting collapse eventually created very large galleries. Some solution takes place as the water moves to the water table but much more is likely to occur below the watertable. Water circulating slowly below the water table dissolves out calcium carbonate and becoming denser, drops to a lower level to be replaced by lighter unladen water. In this manner very large galleries may be formed over a long period of time. The water table may fill several galleries joined by passageways formed along bedding planes of less resistant limestone. The lowering of the water table by regional uplift, valley downcutting, or climate change will drain the galleries and passageways leaving them open for dripstone deposition.

From all indications, Natural Bridge Caverns appears to be a solution cavern formed below the water table and later drained. The dendritic passages of the caverns were formed along two major joint systems trending N 30° E and N 30° W. Lowering of the watertable and drainage of the caverns probably occurred from a combination of valley downcutting and and change in climate to less humid conditions.

All faults occurring in the area are downthrown to the southeast. A major fault south of Natural Bridge Caverns is the Bat Cave fault with a throw of 200 feet, striking N 60° E.

The entrance to Natural Bridge Caverns lies at the end of a collapsed sinkhole approximately 200 feet long, 40 feet wide and 30 feet deep. From the entrance sink to the end of the northermost room the cave trends approximately N 10° W for a straight line distance of 3,125 feet. The natural limestone bridge which can be seen from the gift shop patio and from the trail below is all that remains intact of a huge underground chamber. The size of the sinkhole convinced St. Mary's University spelunkers that there should be more chambers associated with this one. Several groups had explored passageways but none had gone any great distance before having to turn back. While mapping some passageways, the St. Mary's group decided to investigate a narrow passage not previously explored. Their explorations led them through 60 feet of tight crawl space and into the vast chambers we see today. There is evidence that the outer portions of the caverns have been inhabited by man and animals at various times. Spearpoints dating to 5,000 B. C. have been found, as well as jaw bones of a grizzly bear which became extinct over 8,000 years ago. More recent occupants have been coons and bats, neither of which remain in the cave today. Man has also left his mark on the cave--graffiti from 1928 attest to the fact that man has an opposable digit and a superior brain, although the latter does not always operate among picnickers. The only remaining inhabitants of the cave are crickets and spiders.

According to John L. Newcomb the boundary between the Walnut formation and the overlying Kainer formation is near the elevation of the cave entrance. Fossils characteristic of the Glen Rose may be found in the lower parts of the caverns. (See "Glen Rose Fossils", Figure 2,page 34A.)

Many beautiful dripstone and flowstone formations were built up in the caverns after they had been drained and a period of deposition replaced that of solution. Since deposition still occurs throughout a major portion of the cave, glass doors have been installed at both entrance and exit to disturb as little as possible the atmosphere of the caverns. The air temperature remains a constant 70 degrees with 90% humidity. The water temperature inside the caverns is 74°F which is the same as that of Comal Springs as it emerges in Landa Park. This, and the fact that the alignment of the Comal Springs exit and the joint pattern of Natural Bridge are the same, would indicate that this entire area serves as an underground transportation system for water to Comal Springs.

The red clay (Terra Rosa) which can be seen throughout the cave is the residue of limestone solution. It settles in cavities and fills joints and cracks creating an impermeable layer.

References

Geology of Bell County, Texas, University of Texas Bulletin 3016, April 22, 1930. pp. 26-34.

Halliday, William R., Depths of the Earth. Harper & Row, Publishers, New York, 1966, pp. 74-82.

Handouts available through St. Mary's Geology Department.

Historical Geology, Raymond C. Moore, McGraw Hill Book Company, Inc., New York, 1933.

Moore, G. W. and Nicholas, Bro. G., Speleology, D. C. Heath & Co., Boston, 1964, pp. 17.

Newcomb, John H., Geology of Bat Cave Quadrangle Comal and Bexar Counties, Texas., University of Texas (Unpublished thesis), 1971.

Pamphlets obtained from Mr. Harry Heideman of Natural Bridge Caverns.

University of Texas Bulletin 3232, The Geology of Texas, Vol. I, Stratigraphy, E. H. Sellards, W. S. Adkins, F. B. Plummer, August 22, 1932.

The St. Mary's cave-crawlers had to be "wenched" out of the South Caverns at NBC.

GLENROSE FOSSILS

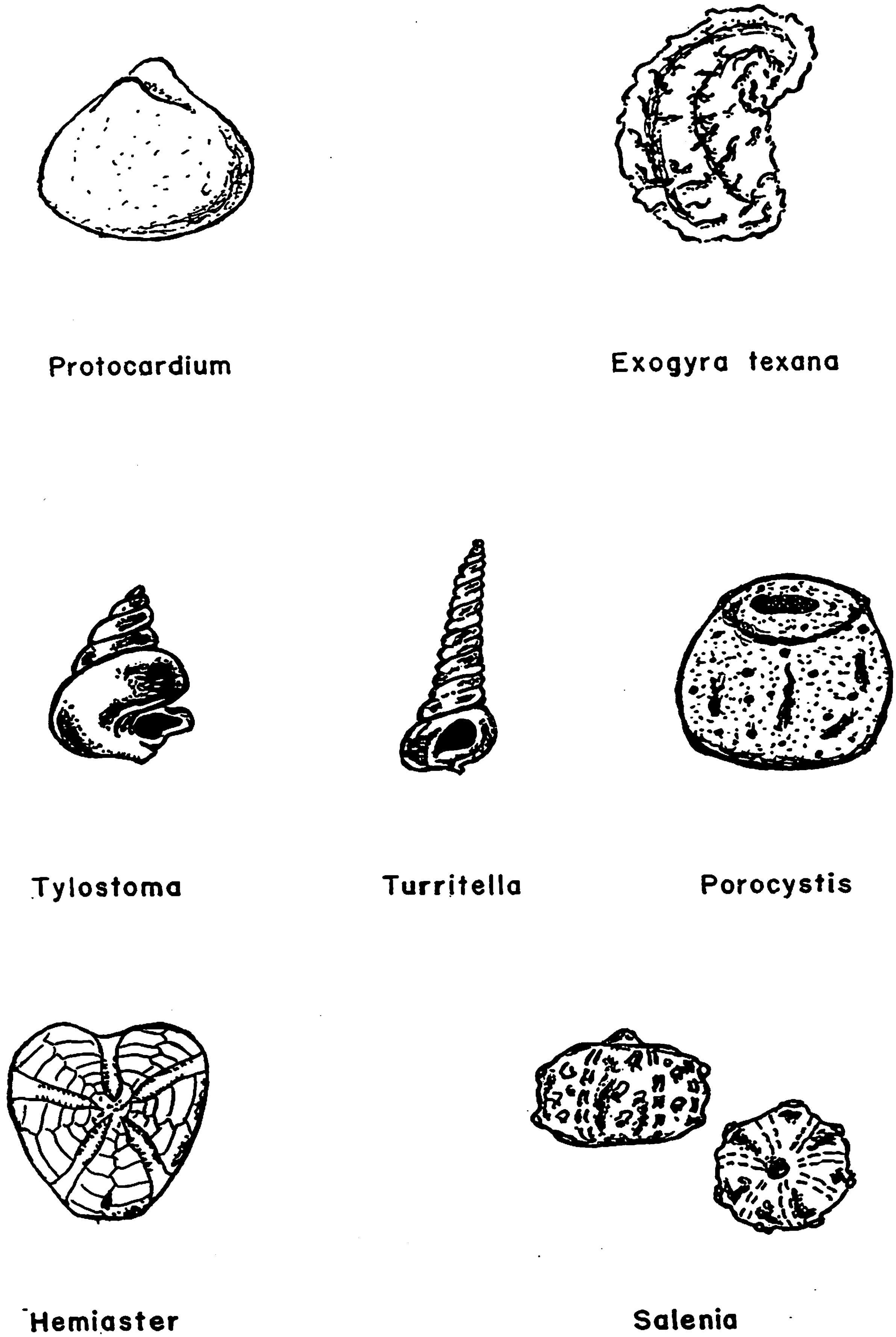
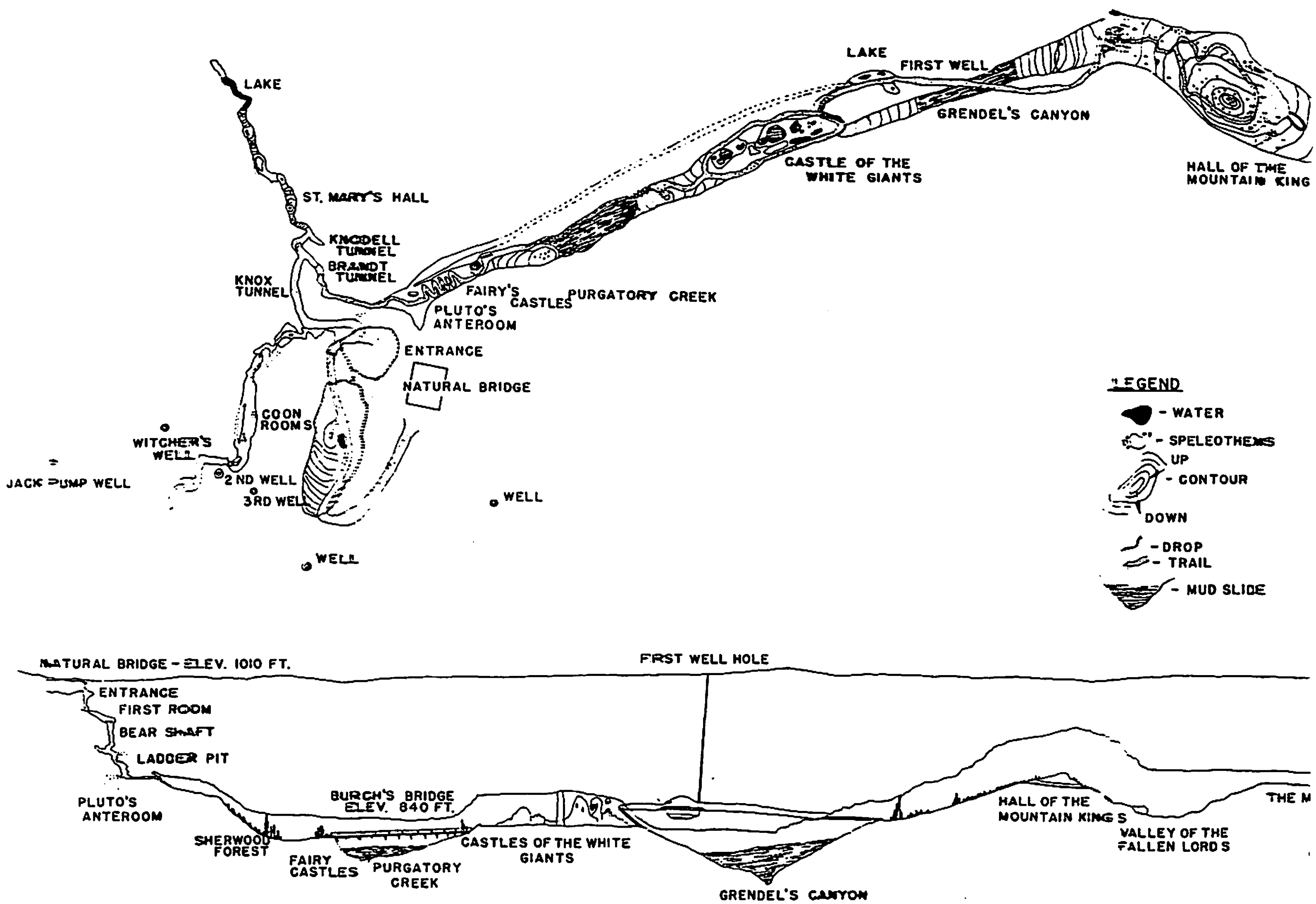


Figure 2

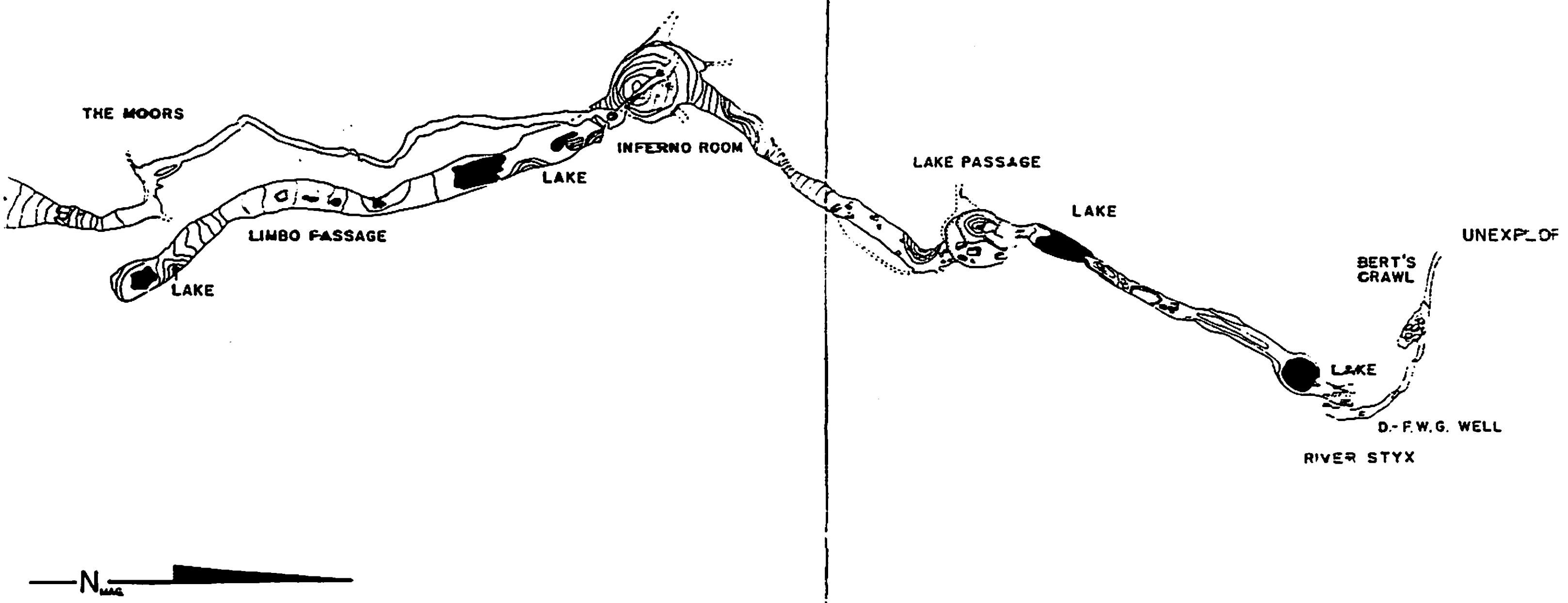


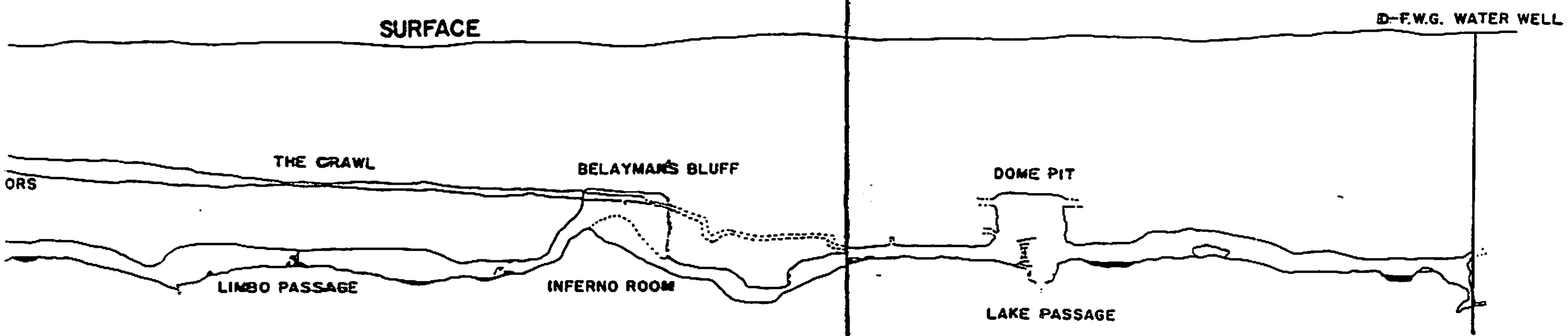
NATURAL BRIDGE CAVERNS

VERTICAL SECTION

SURVEY BY - ST. M.U.S.S. - A.G. - U.T.G. - D.F.W.G.

0 50 100
FEET


THE MOORS
INFERNO ROOM
LAKE
LIMBO PASSAGE
LAKE
LAKE PASSAGE
LAKE
UNEXPL
BERT'S CRAWL
LAKE
D.-F.W.G. WELL
RIVER STYX
N MAG


SURFACE
D-F.W.G. WATER WELL
THE CRAWL
BELAYMAN'S BLUFF
DOME PIT
ORS
LIMBO PASSAGE
INFERNO ROOM
LAKE PASSAGE

REBECCA CREEK SPRING

Wayne Edson and John Mote

STRATIGRAPHY:

COMANCHE SERIES:

TRINITY GROUP:

Travis Peak Formation:

The Travis Peak formation was divided by Hill (1901, pp. 141-144) into three members, which in ascending order are: the Sycamore Sand member, the Cow Creek limestone member, and the Hensell Sand member. The Travis Peak formation has long been regarded as the oldest Cretaceous strata in central Texas. These are the oldest exposed rocks in Comal County.

Sycamore Sand Member:

The Sycamore contains materials characteristic of the first deposits of a transgressing sea and differs in thickness according to the topography of the land surface on which it was deposited. The Sycamore does not crop out in Comal County and it is doubtful that such sands are present beneath the surface.

Cow Creek Limestone:

The Cow Creek limestone member consists of massive grey-white fossiliferous limestone and has a total thickness of about 75 feet. The limestone is honeycombed in some places along the outcrop.

Hensell Sand Member:

The Hensell sand member is composed of buff-colored argillaceous and calcareous fine grained sand containing siliceous and calcareous geodes locally known as Katzenkopfe or cat heads. These are roughly spherical, hollow or partially hollow accumulations of mineral matter from a few inches to more than a foot in diameter. An outer layer of chalcedony is lined with crystals, often perfectly formed, are usually quartz, although calcite and dolomite are also found and, more rarely, other minerals. Geodes are most commonly found in limestone and more rarely in shale. Also found in the Hensell are sandy limestone beds containing glauconite which adds a greenish tint to the buff color.

Glen Rose Limestone Formation:

Where thick sections are exposed at the surface the Glen Rose is easily recognized at a distance because of the characteristic terraces or stair-step topography due to the alternation of limestone and more easily eroded marl beds.

The Glen Rose is arbitrarily divided into two parts which are known as upper and lower members of the Glen Rose limestone. Although alternating limestones and marls are characteristic of the whole formation, the lower member of the Glen Rose contains thicker and more massive limestone beds and is more fossiliferous than the upper member.

GEOMORPHOLOGY

The spring issues from the bottom of the Cow Creek limestone which forms the high cliffs adjacent to the creek bed. The spring has been measured at 2,000 gallons a minute.

The falls and pool are in the Cow Creek limestone, the enlarged area of the pool is due to the action of water flowing over joint patterns and gravity. The massive piece of limestone in the center of the pool has separated from a former joint where the falls were once active. High cliffs of the Cow Creek can be seen bounding Rebecca Creek as it meanders. Many caves are present along a bedding plane in the Cow Creek which is intersecting the many vertical joints in the Cow Creek limestone.

Glen Rose limestone caps the hills of the area and there are several conformable contacts with the Hensell sand member of the Travis Peak formation in the area. Due to the old age of the Travis Peak formation which is exposed in this area it appears to be a horst. Rebecca Creek is a subsequent stream.

The vegetation of the area is primarily plains grass and oak and cedar trees. In Rebecca Creek bed are found cypress trees laden with moss which are suited to the abundance of water.

References

Leet, L. D. and Judson, S., Physical Geology, 3rd edition, Prentice-Hall, Inc., New Jersey, 1965.

George, W. O., Breeding, S. D. and Hastings, W. W., Geology and Ground-water Resources of Comal County, Texas. Geological Survey Water Supply Paper 1138.

Hill, R. T., Geography and Geology of the Black and Grand Prairies, Texas. U. S. Geological Survey, 21st. Annual Report. part 7., 1901.

Pssst... Wanna buy a dirty rock?

KENDALL COUNTY

John Mote

Geologic Description

The rough and rolling topography of Kendall County is characterized by limestone-capped hills typical of the Edwards Plateau. Valleys are formed from stream incisement of materials less resistant than the more resistant cap-rock. The altitude of the land surface in the county increases from 1,100 feet at the southeastern edge to 2,000 feet in the north-central section. Kendall County is within the drainage of the Guadalupe. Surface drainage direction is southeast, aquifer drainage is east-northeast.[1]

Kendall County lies in the subhumid zone of the state. Average annual precipitation is 30.69 inches most of which occurs in May, June, September, and October. The average annual temperature is 68.5° F ranging from 48.7° F in January to 80.7° F in July.

Trending northwestward across the county is a broad low syncline and its associated anticline. The crest and trough plunge gently southward at right angles to the Balcones Fault zone. Several discontinuous northeastward trending faults cross the syncline and anticline. Displacement is small and apparently has little effect on the occurance of ground water.

Exposed rocks in the county range from Early Cretaceous to Recent with the exception of several small bodies of intrusive basalt found in the southeastern area.

Principle Cretaceous water-bearing units of Kendall County are the Hosston, Sligo, and Pearsall formations as well as the Glen Rose limestone. Less important as sources of ground water are the Comanche Peak and Edwards limestone formations and Pleistocene and Recent alluvial deposits. Pre-Cretaceous rocks underlie the Cretaceous and yield only small quantities of fresh or slightly saline water.

The Lower Cretaceous Age rocks in Kendall County are from both of the Trinity and Fredericksburg Groups. The Trinity Group includes the Hosston, Sligo, and Pearsall formations and Glen Rose limestone. The Fredericksburg Group includes the Walnut Clay, Comanche Peak and Edwards limestone formations. The uppermost formation, the Kiamichi, does not occur in Kendall County.

TRINITY GROUP

Hosston and Sligo Formations:

The Hosston and Sligo formations are not exposed in

Kendall County, however data from well logs indicate that the formations thin northward from 330 feet to 235 feet. From this data it is also known that the Hosston in the southern area is conglomerate, sandstone, and dolomite interbedded with shale grading upward into the dolomitic limestone of the Sligo. In the northern area the Hosston is basically the same, but the Sligo changes to alternating sand, sandy dolomite, and limestone beds.

Pearsall Formation:

The Pearsall overlies the Sligo formation and includes the Pine Island Shale, Cow Creek limestone and Hensell Shale Members.

Pine Island Shale:

The Pine Island Shale ranges from 65-75 feet in thickness and does not crop out in Kendall County. It is formed of sandy, fossiliferous dark-blue to grey shale interbedded with thin layers of dolomitic limestone which serves to confine water to the underlying Sligo.

Cow Creek Limestone:

The oldest exposed unit in the county, the Cow Creek member, occurs in the southeastern area where the Guadalupe River has incised into the overlying strata. This member ranges in thickness from 55 feet to 25 feet at the outcrop and consists predominantly of massive white fossiliferous limestone with beds of sand, shale and lignite in the lower and middle parts. In the southern and western areas of the county where the unit is at maximum thickness the Cow Creek yields small quantities of fresh to slightly saline water.

Hensell Shale:

Overlying the Cow Creek is the Hensell member of the Pearsall Formation. The Hensell is an important aquifer in the north and northwestern areas of the county where it consists of loosely cemented conglomerate and sand, sandstone, shale, and marl. The only exposed part of Hensell occurs in the southeastern area along the Guadalupe River where it consists of shale and marl with interbedded layers of sandstone and dolomite. The member is thickest in the western area and thins southeastward interfingering with the overlying Glen Rose limestone.

Glen Rose Limestone Formation:

The contact between the Pearsall and Glen Rose formation is arbitrarily placed at the base of the lowest well-developed limestone beds of Glen Rose. Glen Rose limestone is divided into lower and upper members, George (1952, p.17-18) using a thin limestone bed at the top of a Salenia texana fossil zone as a boundary between the two.

Lower Member:

A massive rudistid limestone and beds of marl, containing Orbitolina texana (Roemer) grading upward into thin beds of limestone, marl and shale make up the basal part of this member. Ripple marks, filled borings, mud cracks, dinosaur tracks and crossbedding found in the upper 50 feet of these beds are characteristic of areas of shallow water. Overlying this zone is the fossiliferous Salenia texana zone. Also found in this zone are fossils of Orbitolina texana (Roemer), Hemiaster sp., crab claws, Porocystis sp., Trigonia sp., and Douvilleiceras sp.

Upper Member:

This member may be divided into lower evaporite beds and overlying marl, 45-50 feet thick; fossiliferous marl containing Orbitolina minuta Douglass grading upward into oyster and rudistid limestone, 100-150 feet thick; calcareous marl, 30-40 feet thick; and marl and calcarenite grading upward into argillaceous dolomite or shale, 160 feet thick. The surface exposures of the blue shale weather to yellowish-brown. The exposed evaporite beds from which the anhydrite has been removed by solution consist of yellow marl and dolomite interbedded with chalky limestone. Also characteristic are the distorted bedding, seeps, and springs. Water from these evaporite beds has a high sulfate content. Water taken from other zones of the upper member of Glen Rose yield small amounts of saline water. High mineralization of the groundwater probably results from slow circulation of water through the limestone.

FREDERICKSBURG GROUP

Walnut Clay:

Marly clay and shell aggregate, ranging in thickness from 3 to 15 feet, containing Echinoids (*Loriolia* sp., *Holectypus* sp.), pelecypods, gastropods, *Ergonoceras* sp., *Dictyoconus* sp., *Porocystis globularis* (Giebel), and abundant *Exogyra texana* (Roemer) denote the Walnut formation.

Comanche Peak Limestone:

The Comanche Peak formation is a marly nodular limestone distinguished from the underlying Walnut by its more resistant nature.

Edwards Formation:

The Edwards overlies the Comanche Peak and is a very resistant cliff forming limestone. It is exposed in many areas of the county and supports a dense growth of cedar trees.

References

1. Report 60; Ground-water Resources of Kendall County, Texas. Texas Water Development Board. Pages 1-13.

2. Bulletin 6210: Ground-water Geology of Bandera County. Pages 13-15.

3. George, W. O. and S. D. Breeden and W. W. Hastings, Geology and Water Resources of Comal County, U. S. G. S. Water Supply Papers. Bulletin 1138, 1952.

This space was reserved for a cartoon. Since St. Mary's believes in innovation, do it yourself!

CASCADE CAVERNS

Larry Faust

Ever since man took his first step in the countryside around the present day town of Boerne, Texas, Cascade Caverns has been there for his exploration and use. The caverns are formed in rocks dating between 70 and 135 million years old.[1] This is determined by the age of shells in the ceiling and other already established correlation criteria. The date of cave formation was likely within the Pleistocene ($\pm$ 1 million years).

Early Texas inhabitants, most likely Apache, used only the first 500 feet of the cave; beyond that point it was completely filled with water. The only entrance was the present day Peep in the Deep which involved a harrowing 60 foot descent by rope ladder from the surface to the cave floor. The present day entrance for tours was not then large enough for man to pass through. The Indians probably used the cave for dwelling and meetings, but because of their superstitions probably did not venture into the cave past a point from which they could see light from the outside.[2] The soot found on the sides of the natural chimney in the cave indicate fires had been built in the cave for cooking and/or for heat and light.[3] One book written about Cascade Caverns tells of a hermit who lived in the cave around 1832 after he had been jilted by his girlfriend. Human bones and a vintage pistol found in the cave are thought to belong to the hermit although no real evidence substantiates the story. It is also rumored that during the Civil War Union sympathizers used the cave, then known as "Hester's Cave", for a hiding place from Confederate soldiers.[4] Since the town of Boerne was settled people of all ages have used the cave and the surrounding area for a playground and picnic area.

In 1927 Dr. Hester sold the property to Mr. and Mrs. Alfred Gray the current owners. Dr. Frank Nicholson, the first real explorer of the cave, obtained permission from the owner to explore Hester's Cave. He placed a flashlight in a fruit jar and swam through underwater portions of the cave surfacing where he found air pockets. After seeing the other portions of the cave, Dr. Nicholson realized its commercial potential and undertook plans for development. Nicholson and a financial backer named Drake formed the Cascade Caverns Corporation and leased the area from Mr. and Mrs. Gray with the stipulation that the corporation could sell the lease and improvements. A group worked for 25 months cleaning out debris from the cave and laying walkways thus enabling the cave to be opened in the mid-30's.

Problems later arose between Drake and Nicholson which resulted in the sale of the lease to a Mr. Peterson of Minneapolis, Minnesota who kept the cave for five years and and then sold to a Mr. Lindberg who kept it for 12 years. Neither Peterson nor Lindberg did any extensive development on the property. A Mr. Ballou bought the lease from Lindberg and made improvements for the next ten years. Flooding in 1964 forced the closing of the cave. A clause in the lease contract stated that if the cave was not in continuous commercial operation the lease would revert to Mr. and Mrs. Gray. This stipulation caused Ballou to sell his lease to Mr. Bridges, the present owner and developer of the area.

GEOLOGY OF CASCADE CAVERNS:

Cascade Caverns is located in Kendall County two-tenths miles south of Cibolo Creek and one and one-half miles north east of Interstate 10. The entrance to the caverns is approximately 1340 feet above sea level and is situated in the lower member of the Glen Rose limestone, Trinity group, Comanche series, Cretaceous system. The average thickness of the lower member is three hundred feet.

The lower member is divided into two units. The lower unit is mostly massive ledge-forming limestone comprised of shell fragments in a lime mudstone or sparry calcite matrix with interbeds of clay. This unit is subject to much variation in thickness and is usually recognized by sporadic rudist and coral reef deposits and the development of several caves in the area. The upper unit usually contains fissile dolomitic shale and dolomite beds in its lower part and alternating beds of clay and limestone in the upper part.

The cave is joint controlled and in many places gives the illusion of faulting but no measurable displacement has been noticed. Permeability of the upper room is very high due to reef development. The lower room is much drier marly limestone with some occurrence of spar calcite replacement. Fossils in the lower room are tentatively identified as <u>Gryphaea</u> <u>belviderensis</u> (Hill and Vaughan).

1685 feet from the cavern entrance is a joint controlled sinkhole trending southwest exactly parallel with one of the major joints in the main cavern. Mr. Bridges, manager of the caverns, believes that the sink and the caverns are connected however, due to the bulk of scuba tanks, a diver was unable to ascertain whether there is a connection. The sink is interesting because of its vertical walls and the occurrence of many rudistid fossils. A mapping crew has determined that the sink extends for 1217 feet and has a total depth of 76 feet.

References

1. San Antonio Express Newspaper, May 26, 1932.

2. H. F. Tweedy. Hollands-The Magazine of the South. "Cascade Caverns, Texas' 12-mile Wonder Cave". August, 1932.

3. Ibid; Tweedy

4. Ibid; Tweedy

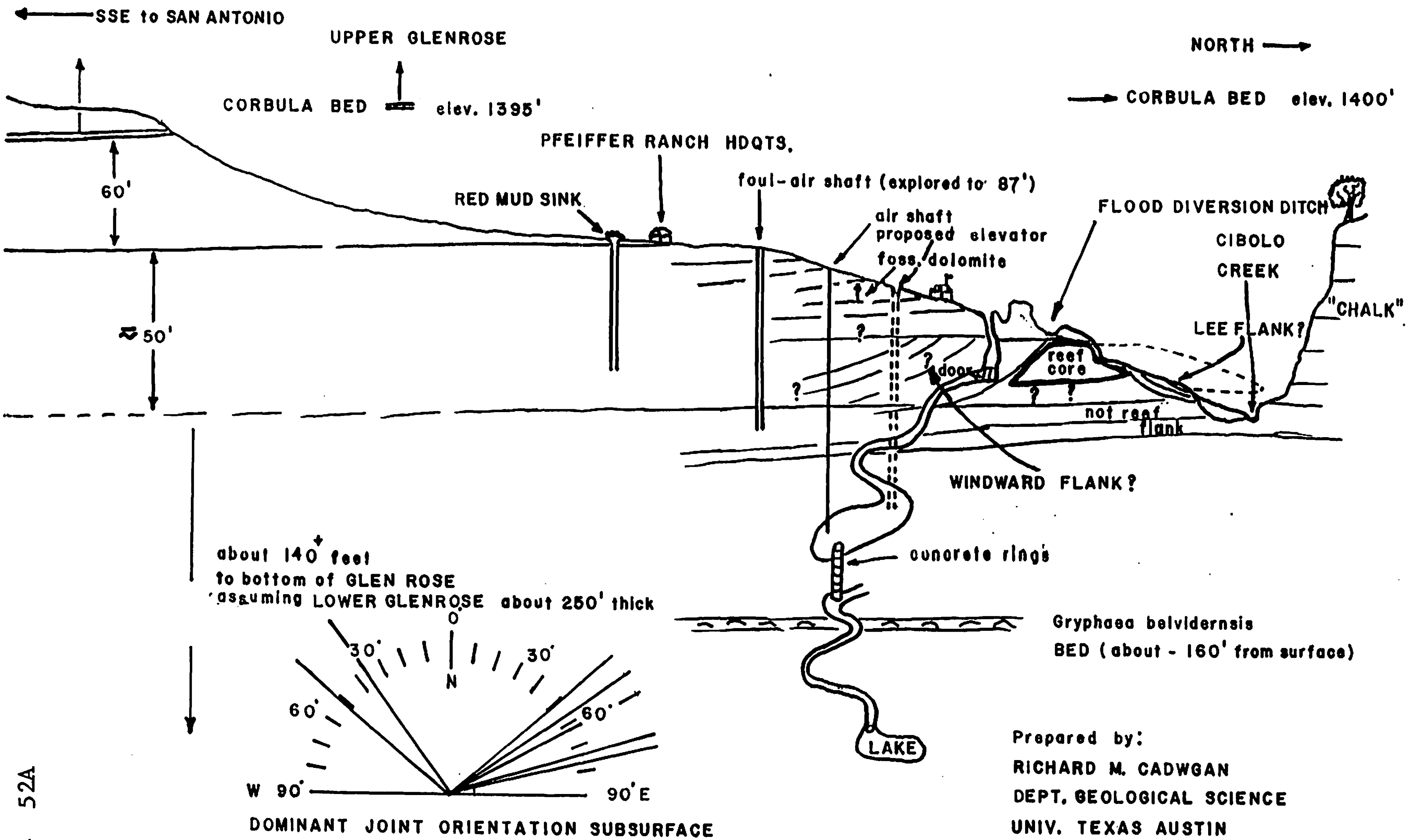
Telephone interview with Mrs. Gray.

Reeves, Richard D. Ground-Water Resources of Kendall County. Texas Water Development Board Report 60., 1967.

Strickland, F. L. and C. I. Smith and R. E. Lozo. Lower Cretaceous Trinity Deposits of Central Texas. Report of Investigations No. 71., 1971.

PRELIMINARY CROSS-SECTION CASCADE CAVERNS AREA

NO VERTICAL SCALE INTENDED



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UNIV. TEXAS AUSTIN
FEB.-15-73

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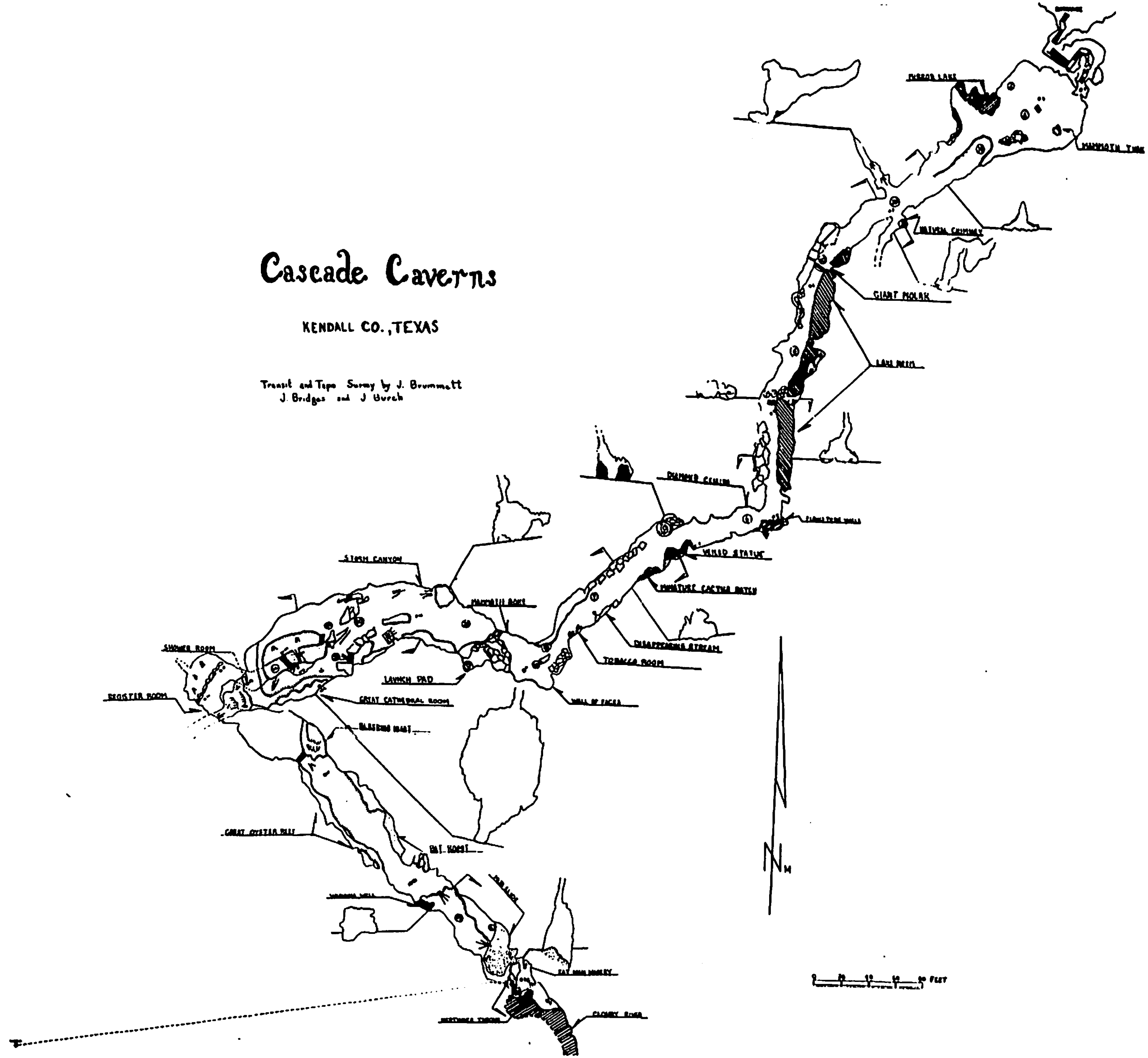
Cascade Caverns
KENDALL CO., TEXAS
Transit and Tape Survey by J. Brummett
J. Bridges and J Burch
MIRROR LAKE
NATURAL CHIMNEY
GIANT MOLAR
DIAMOND CEILING
VENUS STATUE
MINIATURE CACTUS PATCH
DISAPPEARING STREAM
TOBACCO ROOM
WALL OF FACES
STORM CANYON
MAMMOTH BONE
SHOWER ROOM
REGISTER ROOM
LAUNCH PAD
GREAT CATHEDRAL ROOM
GREAT OYSTER BED
BAT ROOST
CLOUDY RIVER
N
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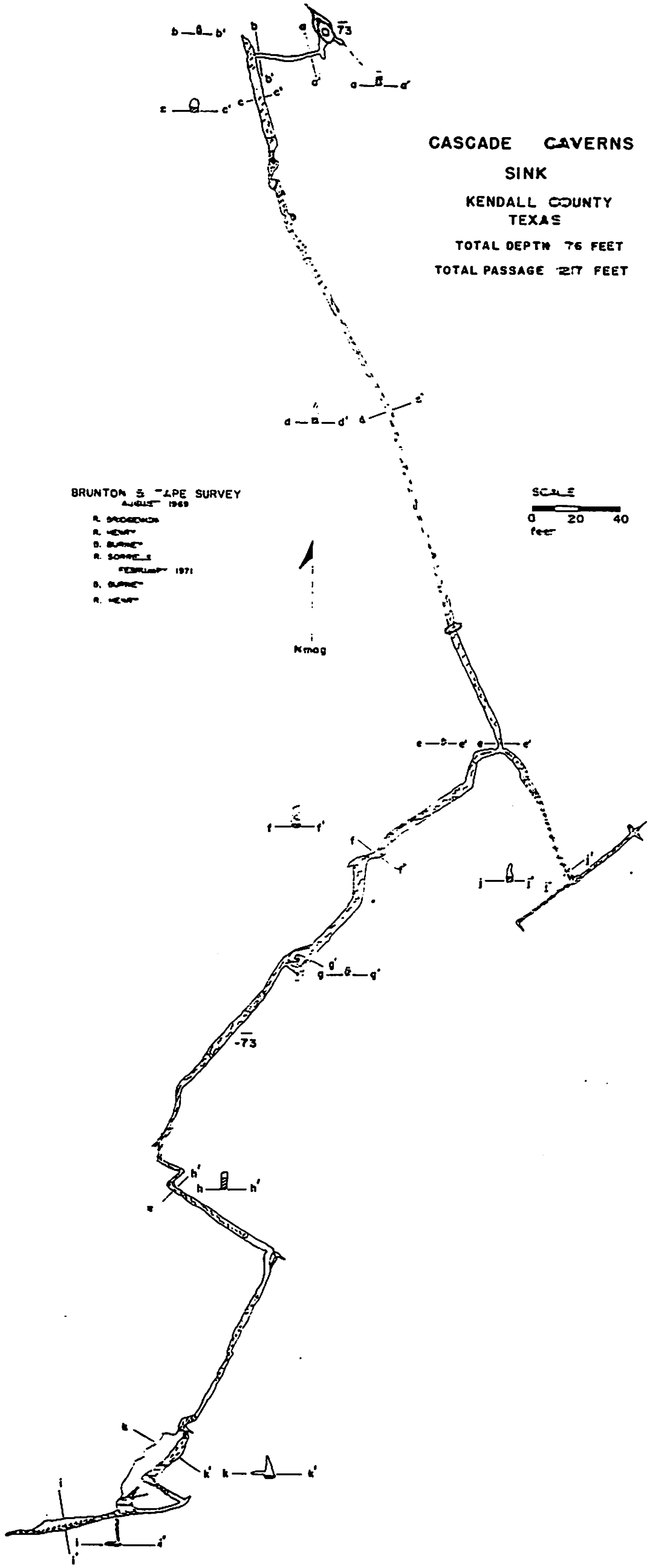
FEET


CASCADE CAVERNS
SINK
KENDALL COUNTY
TEXAS
TOTAL DEPTH 76 FEET
TOTAL PASSAGE 217 FEET
BRUNTON & TAPE SURVEY
1969
1971
SCALE
0 20 40
feet
Kmog
73
-73

WATER ANALYSIS REPORT

Jose Mulet and Joe Sanchez

The tests were performed in a semi-micro analytic fashion. That is to say, only small quantities of samples and reagents were employed. All of the titration reagents were introduced by means of graduated micro-burette. The La Motte Water Analysis kits were employed in the water tests. The sites whose water was analyzed were Cascade Caverns and Natural Bridge Caverns. The results were in parts per million where applicable.

I. Cascade Caverns

A. List of samples and their locations

1. Sample A - 1st lake from entrance
2. Sample B - 2nd lake from entrance
3. Sample C - Hand-disappearing pool
4. Sample D - Salamander pool
5. Sample E - from dripping stalactite
6. Sample F - Drinking water from ticket office (originates from 225 foot well)

B. List of Tests Performed

1. Chlorine
2. pH

3. CO_2

4. Carbonate alkalinity as $CaCO_3$

5. Bicarbonate alkalinity as $CaCO_3$

6. Total hardness

7. Magnesium concentration

8. Calcium concentration

C. Table (next page) - Chemical parameters of Cascade Caverns

D. Comments and Conclusion

1. The absence of chlorine is normal for natural waters such as these. As it was noted before, the positive results of sample C may have been due to the already existing yellow color. The color may somehow be associated with the fact that the water sample was from the hand-disappearing pool i.e. many hands were introduced into the pool and the results may have been because of soiled hands.

2. Surface waters normally contain less than 10 ppm free carbon dioxide. However, some of the samples contained a considerable amount of free CO_2. This high concentration of CO_2 is essential for making of carbonic acid which is responsible for converting $CaCO_3$ to $Ca(HCO_3)_2$. Therefore, the sample with high concentrations of CO_2 are also represen-

Chemical parameters of Cascade Caverns

Sample	Chlorine	Carbonate alk. as $CaCO_3$	Bicarb alk. as $CaCO_3$	Total hardness	Calcium	Magnesium	pH	CO_2
A	0	40 ppm	220 ppm	250 ppm	175 ppm	75 ppm	7.0	3 ppm
B	0	0	354 ppm	285 ppm	215 ppm	70 ppm	7.0	23 ppm
C	.1ppm*	0	366 ppm	290 ppm	200 ppm	90 ppm	7.0	31.25 ppm
D	0	0	326 ppm	300 ppm	190 ppm	110 ppm	7.0	9.75 ppm
E	0	56 ppm	262 ppm	240 ppm	195 ppm	45 ppm	7.0	4.7 ppm
F	0	0	390 ppm	297.5 ppm	155 ppm	142.5ppm	8.5	13.25 ppm

* This test may be invalid because test depends upon yellowing of the water solution and the water sample was yellowish already.

tative of the sample with a relatively high concentration of bicarbonates (HCO_3). While the samples with low concentrations reveal not only less bicarbonate levels but also carbonate (CO_3) levels that were non-existent in the other samples with lowered CO_2 concentration.

3. The total hardness of all the samples was rather high, even for the drinking water which had a total hardness of 297.5 ppm. Waters with a total hardness of above 180 ppm are considered to be very hard. The 142.5 ppm of magnesium came precariously close to the 150 ppm limit set by the U.S. Public Health Service. The total hardness of the water was not greater than the sum of the carbonate and bicarbonate alkalinity. Therefore, there is no excess of non carbonate hardness. This would have been indicative of considerable amounts of chloride and sulfate ions.

4. The calcium concentration level exceeded the magnesium concentration in all the samples. The excess ranged from 1.09 to 1 in sample F to 4.3 to 1 in sample E. The presence of calcium is indicative of the many limestone formations that are associated with the water. However, the magnesium that was detected denotes the possibility of there being dolomite in which about half of the Ca^{++} is

replaced by Mg^{++} ions to yield the empirical formula $MgCa(CO_3)_2$.

5. The pH readings of the sample ranged from 7.0 to 7.5. This is indicative of a neutral solution. This means that the buffering system is functioning properly. Thus in this system the acidic H_2CO_3 and the basic $Ca(OH)_2$ are in such concentrations that their salts neutralize incoming acids and bases. However, the bicarbonate ion (HCO_3^-) is amphoteric i.e. it can act as either a base or an acid. An amphoteric species can act as a buffer.

For example:

When acid is added: $HCO_3^- + H^+ \longrightarrow H_2CO_3$
NB: H^+ is tied up in H_2CO_3

When base is added: $HCO_3^- + OH^- \longrightarrow HOH + CO_3$
NB: OH^- is tied up in HOH (water)

Incidently the normal pH range of normal water is 5.0 to 8.5. Therefore the pH concentration is at a safe level.

E. Coliform count - Pour-plate technique was used and was performed by San Antonio Metropolitan Health Department.

1. Sample about 24 hours old when tested

2. Table of results

Sample		Coliform Count
A	-	15/100 ml
B	-	54/100 ml
C	-	2/100 ml
D	-	46/100 ml
E	-	0/100 ml
F	-	0/100 ml

3. Maximum safe standard for potable water is 1/100 ml as set up by U.S. Public Health Service.

II. Natural Bridge Caverns

A. List of samples and their locations

1. Sample A - pool from Sherwood forest
2. Sample B - pool below King's Chandelier
3. Sample C - dripping stalactite on right of Emerald Lake
4. Sample D - drinking fountain close to exit

B. List of Tests Performed

1. Chlorine content
2. Carbonate alkalinity as $CaCO_3$
3. Bicarbonate alkalinity as $CaCO_3$
4. Total hardness
5. Calcium ion concentration
6. Magnesium ion concentration
7. pH
8. CO_2 content

C. Table (next page) - Chemical parameters of Natural Bridge Caverns

D. Comments and Conclusion

1. The samples tested revealed no chlorine which is normal for natural waters.

Chemical parameters of Natural Bridge Caverns

Sample	Chlorine	Carbonate alk. as $CaCO_3$	Bicarb alk. as $CaCO_3$	Total hardness	Calcium	Magnesium	pH	CO_2
A	0	0 ppm	29 ppm	140 ppm	75 ppm	65 ppm	7.0	1.15 ppm
B	0	0 ppm	24 ppm	115 ppm	65 ppm	50 ppm	7.0	1.50 ppm
C	0	0 ppm	26 ppm	160 ppm	95 ppm	65 ppm	7.0	5.00 ppm
D	0	0 ppm	58 ppm	240 ppm	155 ppm	85 ppm	7.0	15.00 ppm

2. Unlike a few samples from Cascade Caverns, none of the samples from Natural Bridge Caverns had any carbonate alkalinity as $CaCO_3$. However, the bicarbonate alkalinity of Natural Bridge Caverns was in lesser concentrations than in Cascade Caverns in the samples tested.

3. The CO_2 level of the Natural Bridge Cavern samples were on the average less than those of Cascade Caverns. It should be noted that usually the samples with higher CO_2 concentrations had higher bicarbonate alkalinity levels as in Cascade Caverns. CO_2 may be indicative of limestone solution due to conversion into carbonic acid (H_2CO_3) when CO_2 combines with water. The carbonic acid is responsible for the chemical conversion of $CaCO_3$ to $Ca(HCO_3)_2$, i.e. calcium carbonate to calcium bicarbonate (the latter being a more soluble form).

4. The total hardness is also less than any of the samples from Cascade Caverns. It should be noted that the total hardness exceeded the total alkalinity concentrations. This may be indicative of various amounts of chloride and sulfate ions which comprise an excess known as "noncarbonate hardness." This is an important factor to consider when treating potable water by ion exchange methods. Unlike the samples from Cascade Caverns, the NBC samples had much smaller

differences between the calcium and magnesium ion concentrations. In all cases, however, the calcium ion concentration exceeded the magnesium ion concentration. Calcium is indicative of limestone while magnesium could designate the existence of dolomite in which half of the Ca^{++} is replaced by Mg^{++} to give the empirical formula $MgCa(CO_3)_2$.

5. The pH concentrations in general were very stable at 7.0 (which is neutral). This neutral solution is maintained by means of a good buffering system also. This means that the acidic H_2CO_3 and basic $Ca(OH)_2$ are in such concentrations that they and their salts neutralize incoming acids and bases. It is interesting to note that the bicarbonate ion (HCO_3^-) is amphoteric, i.e. it can act as either a base or an acid. Such amphoteric species make good buffers as well.

For example:

When acid is added: $HCO_3^- + H^+ \longrightarrow H_2CO_3$
NB: H^+ is tied up in H_2CO_3.

When base is added: $HCO_3^- + OH \longrightarrow HOH + CO_3^=$
NB: OH^- is tied up in HOH (water).

E. Coliform Count of NBC Water Samples

1. Pour Plate technique employed.

2. Tests conducted by San Antonio Metropolitan Health Department.

3. Sample about 24 hours old when tested (samples kept at low temperatures at all times).

4. Table:

Sample		Coliform Count
A	-	--- (see note below)
B	-	0
C	-	0
D	-	0

Note: This particular sample contained a confluent growth of microorganisms that made determination of coliform organisms impossible. This confluent growth may be due to the fact that the pool where the sample was taken had mud and may have been standing there for quite some time causing it to become contaminated.

5. Maximum safe coliform standard for potable water is 1/100 ml as set up by U.S. Public Health Service.

A NOTE ON SAN ANTONIO'S WATER

Evan Black

Situated on the contact line between the Edwards Plateau and the Gulf Coast Plain, San Antonio ranges in elevation from 485 feet above sea level to over 1500 feet. Along a line running from northeast to southwest, the city is divided into two entirely different geologic regions. To the north of this line are narrow belts of the Gulf Cretaceous, including the Navarro, Taylor, Austin, Eagle Ford, and Woodbine groups.

To the south of this line are the groups of the Eocene, including the Midway, Wilcox, and Claibourne groups. Along their contact line are distinct faults that are easily viewed in many parts of the city, exemplified in the hills crossing San Pedro, Blanco and other north-south streets. One example of this fault system is the fault upon which San Antonio College is situated. Also, across the street from this institution is San Pedro Spring which results from a fault.[1] This Spring helped influence the birth of the settlement of the area by Spanish missionaries and settlers in the 17th century.

To the north of this fault zone, the topography is one of rolling hills and poor lime soil. To the south, however, the soil is rich, black, and highly conducive to farming, particularly in the area south of Kelly Air Force Base. In this area many of the farm products sold by local merchants and grocers are produced.[2] Among the varied products cultivated are flowers grown exclusively for use on certain religious holidays, such as Easter and All Saints Day. Regardless of how undesirable land in northern Bexar County may be for cultivation, from it emerges the water needed for life in Bexar County.

San Antonio is unique in that it draws all of its water supply from wells drilled into the Edwards Aquifer and from spring-fed streams and creeks.[3] No surface water is used for public drinking water. In this, San Antonio and the other towns of the county differ from other metropolitan areas which depend on surface water for their public facilities. Even the surface water that exists, though, is spring fed. The San Antonio River originated from springs near the present Olmos Basin.[4] At present, due to the vast demand San Antonio has placed on the aquifer, the springs feeding the San Antonio River have lost their capacity and the present river is fed from wells, thus it is now a man-made body of water. San Pedro Spring is also dying, though during wet seasons a flow does exist. The city's demand for water is curtailing the pressure needed for the spring to flow.

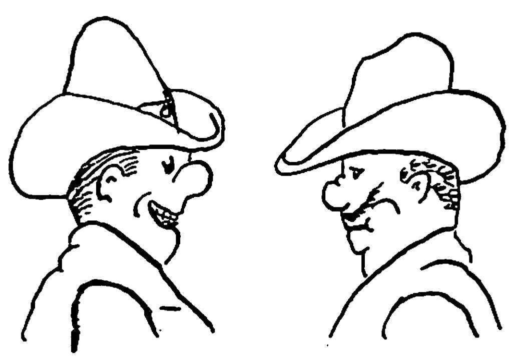
A curious aspect of San Antonio is the direction in which it is growing. From a geological viewpoint, San Antonio is growing in the wrong direction. The city, in its north-northwesterly growth pattern, is moving into the Edwards Aquifer recharge zone and thereby endangering its own water supply. The reasons for this direction of growth go back to the period between 1920-1940 when San Antonio experienced economic prosperity in the 1920's, followed by the WPA projects of the Depression of the 1930's. During the 1920's, San Antonio began to grow from a small cattle town into a modern city.[5] Up to that time the far north side of town was the Ursuline Academy or approximately one mile north of the Alamo.[6] But as the people's wealth increased from business success, oil fortunes and cattle empires, they chose to build their mansions to the north for the view which the rolling hills above the fault zone afforded.

During the 1930's many fortunes were lost and San Antonio's growth rate dwindled. However, with the advent of the WPA, the airport was constructed at its present site and stimulated new growth again toward the north. A football arena, Alamo Stadium, was constructed by WPA and also situated on the northside. Much blasting was necessary for its construction due to the resistance of the Austin limestone. Had the city grown toward the south, onto the flat land along the San Antonio River, none of the problems of shifting foundations, poor soil conditions, or endangered water would be present.

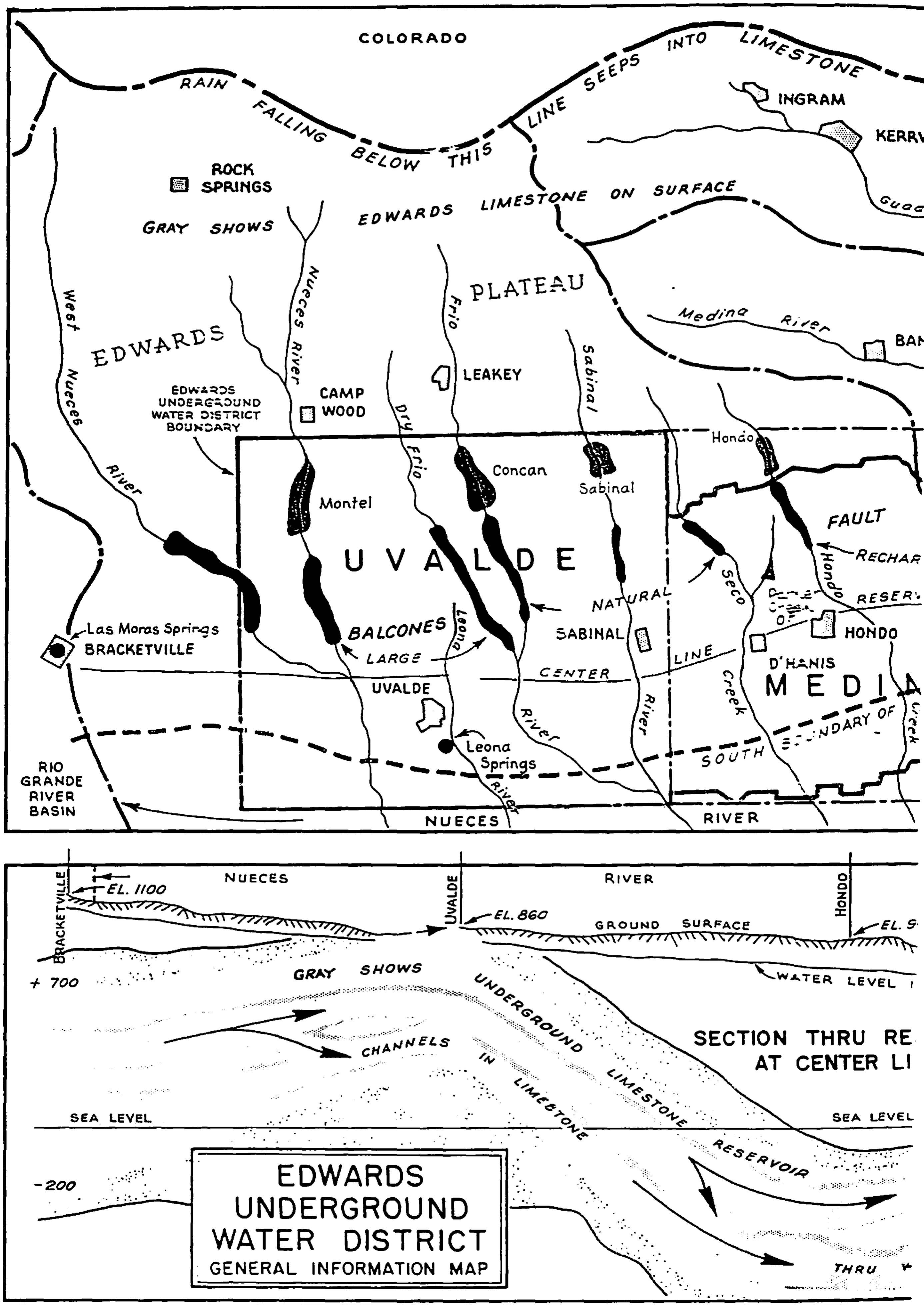
The further population growth of Bexar County extends towards the north, the greater the pollution of the water. For a graphic view of the ground water pollution problems, see Figures 3 and 4. Currently the controversy over development of a new town northwest of the city centers around how water will be affected in San Antonio. Obviously, any sewage affects water downstream. Indeed, even the septic tanks of ranchers and farmers increase the bacteria count above the natural rate as it seeps down through the water table. Thus, the geologic characteristics of the region have, and will continue to have, an effect on the development of San Antonio. The danger to the aquifer by the Corporation New Town is the subject of legal controversy at the present time. Pending a legal decision, based on geological reports which must be approved by the Edwards Underground Water District, several ecological organizations have been soliciting funds through the media for the purpose of continuing action to higher courts.[8]

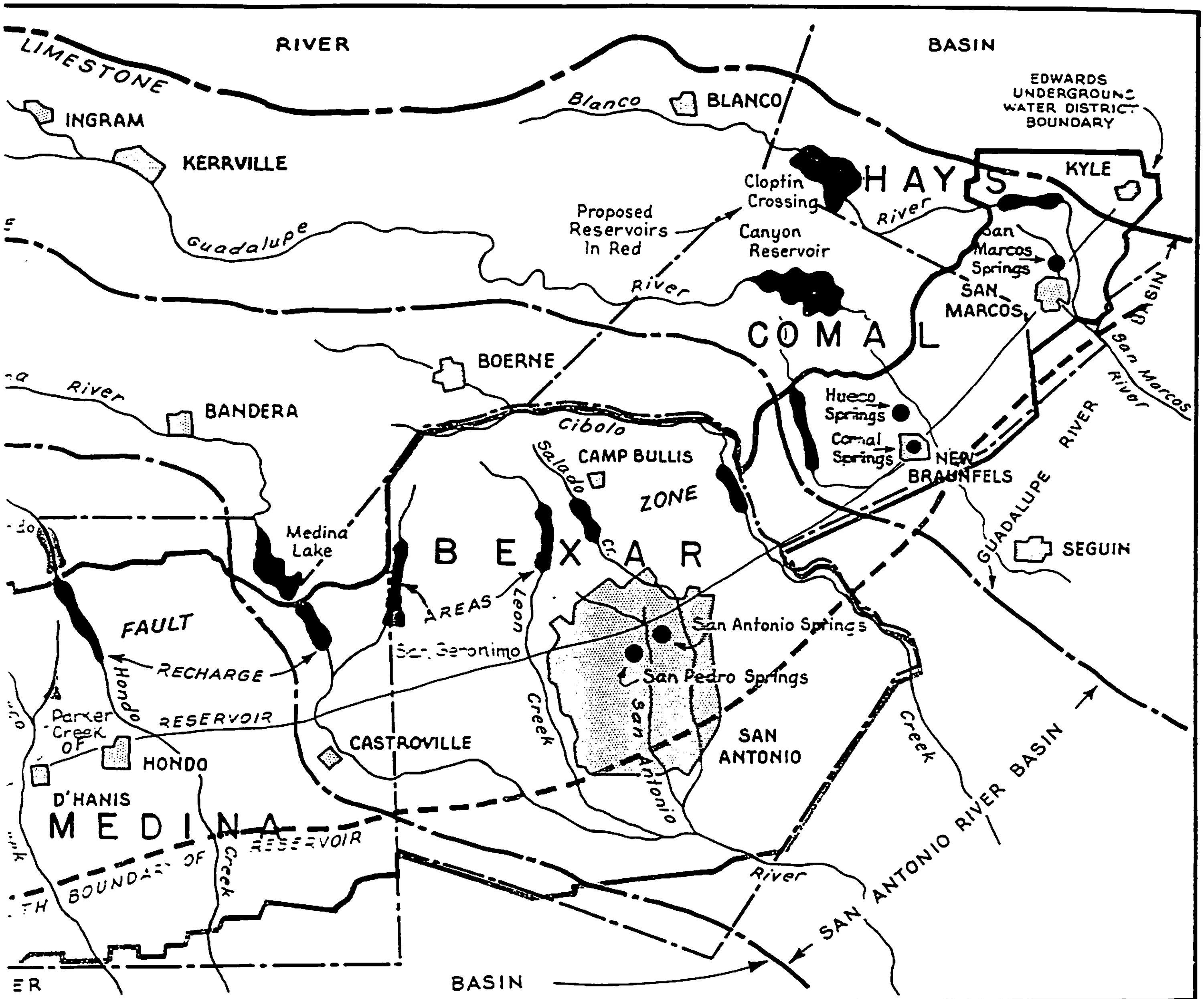
References

1. City of Flaming Adventure, The Naylor Company, 1949, p.6.
2. San Antonio Light, January 28, 1962, Sunday, p. 200.
3. San Antonio Light, January 28, 1962, Sunday, p. 201.
4. Alluring San Antonio, Lillie May Hagner, 1947, p. xiii.
5. City of Flaming Adventure, The Naylor Company, 1949, p. 195.
6. Alluring San Antonio, Lillie May Hagner, 1947, p. 82.
7. The Time Between the Wars, Jonathan Daniels, 1966, p. 12, 299.
8. Advertisement, San Antonio Express, November, 1972, by the following organizations: The American Association of University Women, The League of Women Voters, Citizens for a Better Environment, The Sierra Club.

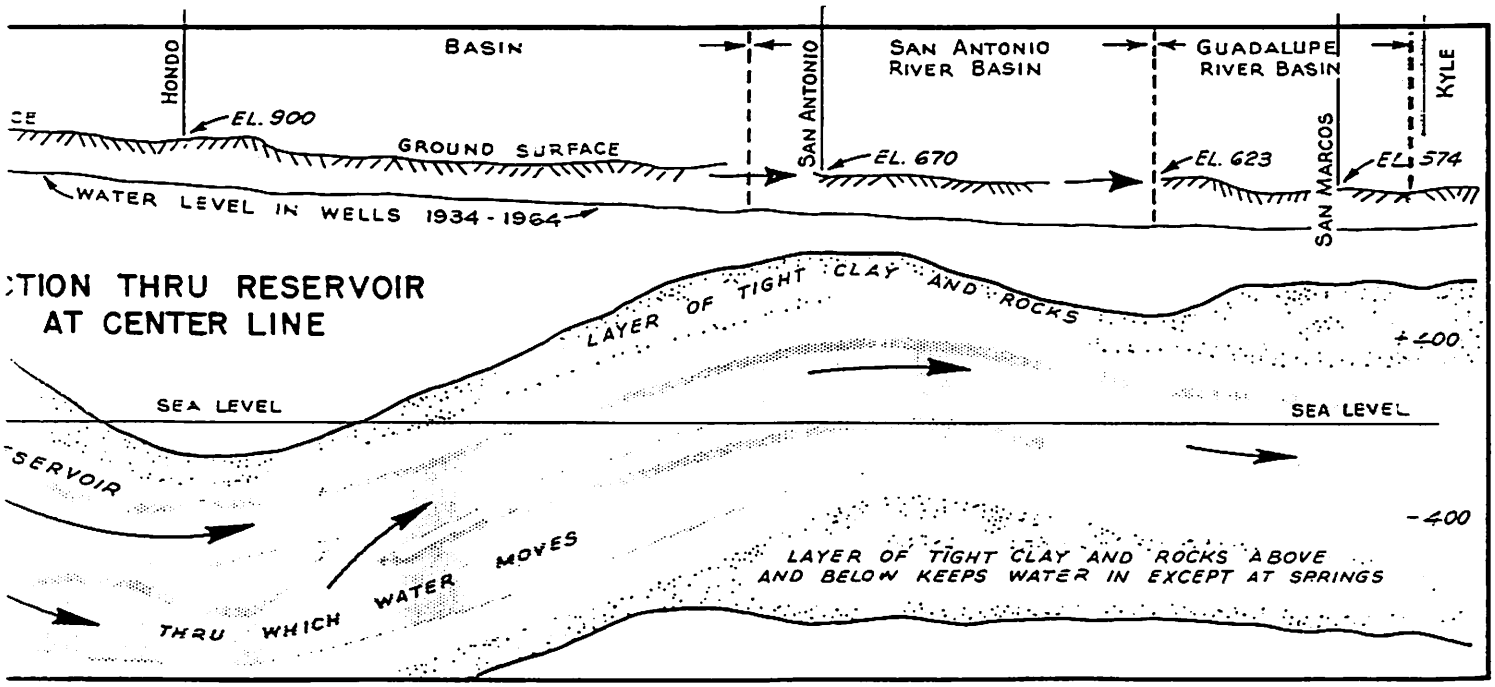


Go South young man. Go south!


COLORADO
RAIN FALLING BELOW THIS LINE SEEPS INTO LIMESTONE
INGRAM
KERRV
ROCK SPRINGS
GRAY SHOWS EDWARDS LIMESTONE ON SURFACE
Guad
EDWARDS PLATEAU
Medina River
BAN
West Nueces River
Nueces River
Frio
Sabinal
LEAKEY
CAMP WOOD
EDWARDS UNDERGROUND WATER DISTRICT BOUNDARY
Hondo
Montel
Concan
Sabinal
Dry Frio
FAULT
RECHAR
UVALDE
NATURAL
Seco
Hondo
RESER
Las Moras Springs
BRACKETVILLE
BALCONES
Leona
LARGE
SABINAL
HONDO
CENTER LINE
D'HANIS
MEDINA
UVALDE
River
River
Creek
Creek
SOUTH BOUNDARY OF
Leona Springs
RIO GRANDE RIVER BASIN
River
NUECES RIVER
BRACKETVILLE
EL. 1100
NUECES
UVALDE
EL. 860
RIVER
HONDO
GROUND SURFACE
EL. 9
WATER LEVEL
+ 700
GRAY SHOWS UNDERGROUND LIMESTONE RESERVOIR
CHANNELS IN LIMESTONE
SECTION THRU RE
AT CENTER LI
SEA LEVEL
SEA LEVEL
-200
THRU
EDWARDS UNDERGROUND WATER DISTRICT
GENERAL INFORMATION MAP

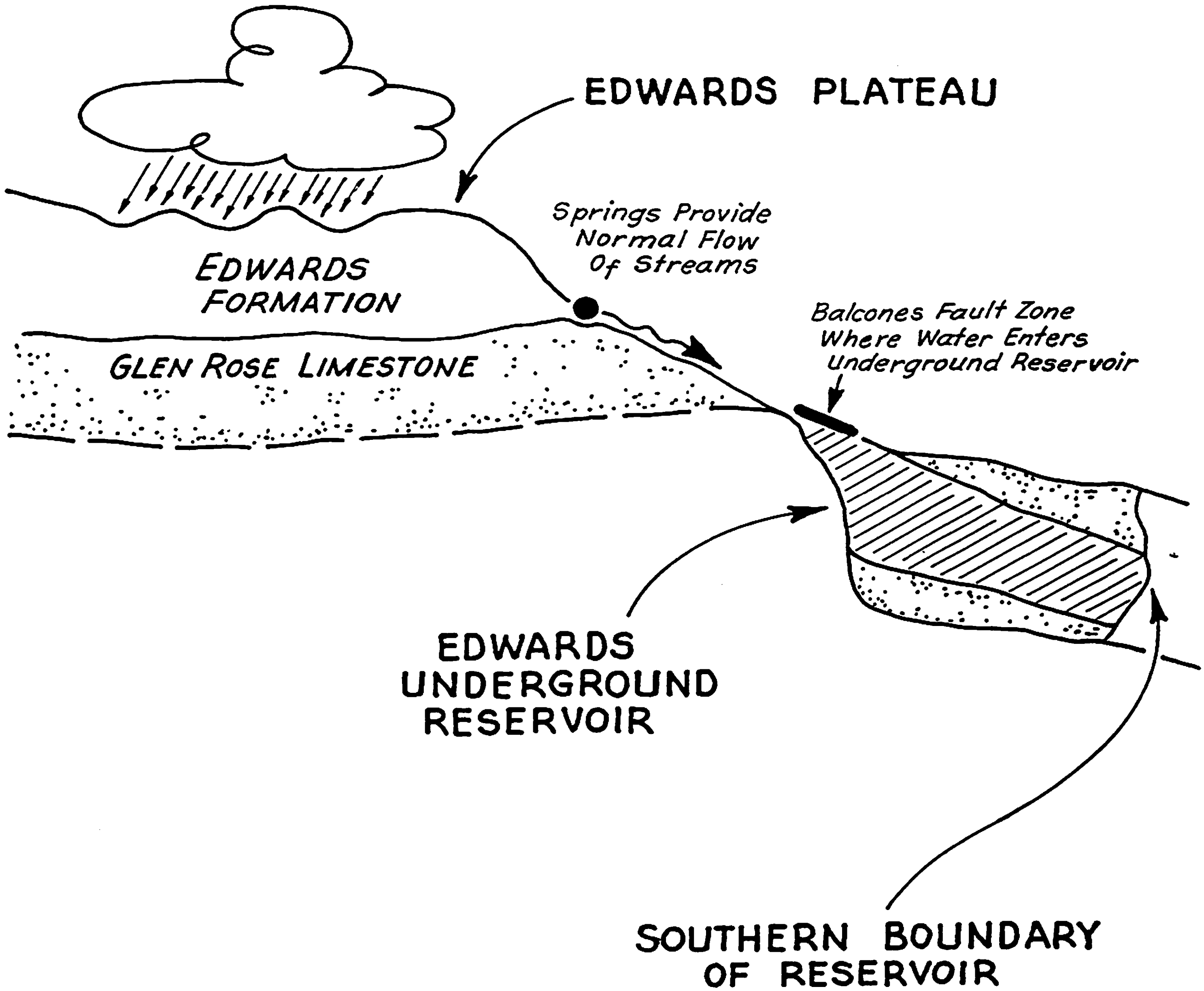


RIVER
BASIN
LIMESTONE
Blanco
BLANCO
INGRAM
KERRVILLE
EDWARDS UNDERGROUND WATER DISTRICT BOUNDARY
KYLE
HAYS
Cloptin Crossing
River
Proposed Reservoirs In Red
Canyon Reservoir
Guadalupe
River
San Marcos Springs
SAN MARCOS
COMAL
BOERNE
BASIN
San Marcos River
River
BANDERA
Cibolo
Hueco Springs
Comal Springs
CAMP BULLIS
Salado
NEW BRAUNFELS
GUADALUPE RIVER
ZONE
Medina Lake
BEXAR
SEGUIN
FAULT
AREAS
Leon
San Antonio Springs
San Geronimo
San Pedro Springs
Hondo
RECHARGE
Parker Creek
RESERVOIR
OF
CASTROVILLE
Creek
San Antonio
SAN ANTONIO
HONDO
Creek
D'HANIS
MEDINA
RESERVOIR
SAN ANTONIO RIVER BASIN
BOUNDARY OF
Creek
River
SAN ANTONIO RIVER BASIN
BASIN



HONDO
BASIN
SAN ANTONIO
SAN ANTONIO RIVER BASIN
GUADALUPE RIVER BASIN
KYLE
EL. 900
GROUND SURFACE
EL. 670
EL. 623
SAN MARCOS
EL. 574
WATER LEVEL IN WELLS 1934 - 1964
CTION THRU RESERVOIR AT CENTER LINE
LAYER OF TIGHT CLAY AND ROCKS
+400
SEA LEVEL
SEA LEVEL
-400
RESERVOIR
THRU WHICH WATER MOVES
LAYER OF TIGHT CLAY AND ROCKS ABOVE AND BELOW KEEPS WATER IN EXCEPT AT SPRINGS

WATER MOVEMENT FROM NORTH TO SOUTH ACROSS THE AREA



BANDERA COUNTY

Charles Anderson, Linda Perez, and John Mote

Geology

Bandera County is in southwest central Texas at the south edge of the Edwards Plateau between longitudes 98°45'W and 99°37'W and latitudes 29°33'N and 29°54'N. (Figure 5).

Bandera County is underlain by Paleozoic rocks on which the Lower Cretaceous sedimentary rocks were deposited. The remnants of these resistant Fredericksburg and Washita limestones only show up now on high hills and interstream areas. The Glen Rose limestone of the Trinity group is the thickest outcrop in the county. There are some minor alluvial deposits along the stream valleys. These deposits are small remnants on hilltops, in fills of old meander channels, and floodplain deposits. Alluvium ranges in age from Pliocene to Recent. The maximum thickness will be found in the major stream valleys where the deposits form broad valley flats. The thickness is from a very thin portion to about 50 feet with beds of gravel, sand, silt, and clay. The alluvium is highly permeable, but the areas are small and are not important as aquifers.

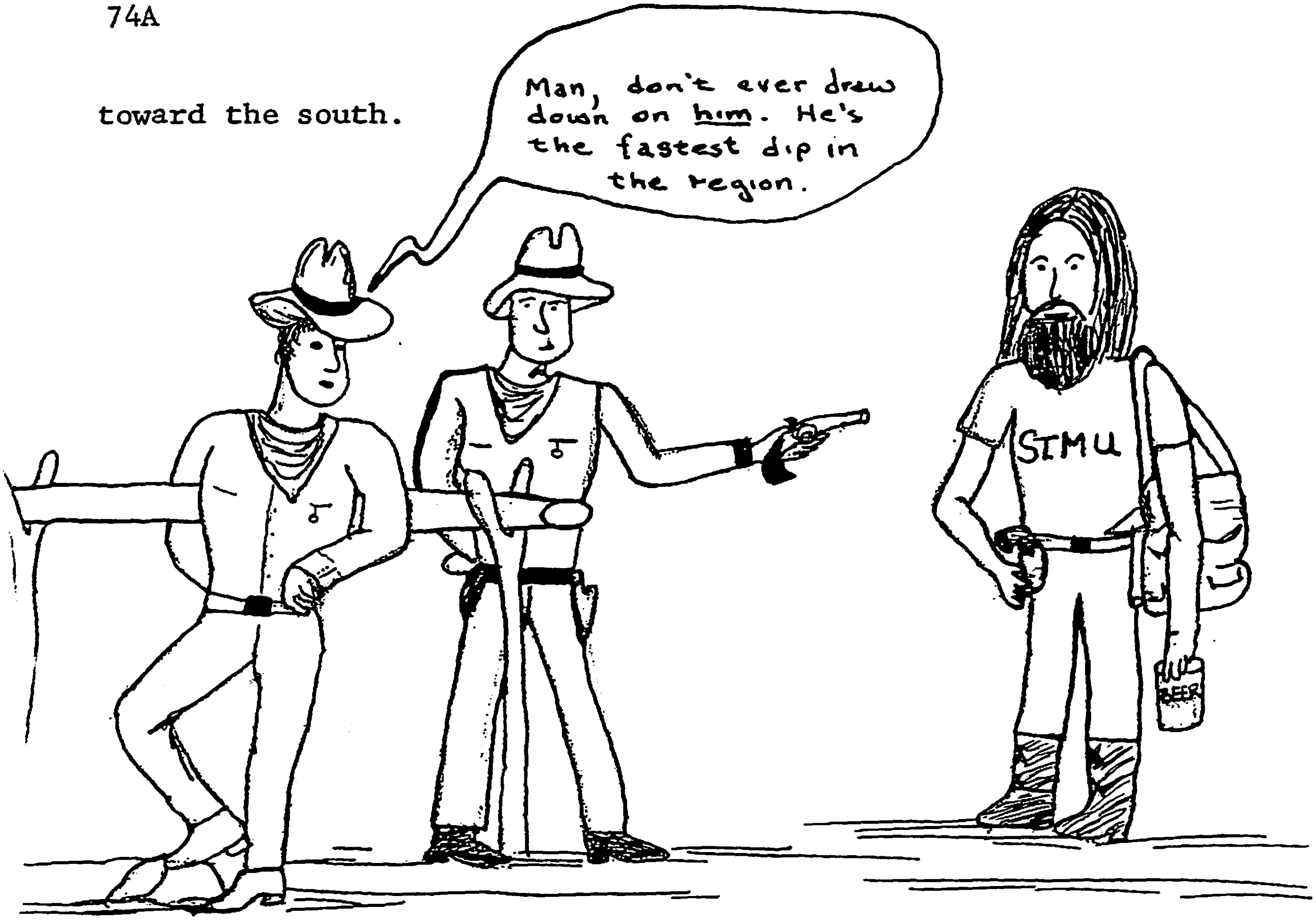
Hills in the Edwards Plateau range from 1500 to 2300 feet in elevation. The hills are covered by rich black or brown soil supporting grass, shin oak, and cedar. In places the soil contains numerous pebbles and cobbles of chert from the Edwards limestone. In the bottom lands next to the streams, there is a good growth of elm, sycamore, walnut, live-oak, pecan and cypress.

Pre-Cretaceous rocks are not exposed in Bandera County, and little is known about these rocks except from the logs of oil tests in nearby counties which indicate that they consist, at least in part, of hard black noncalcareous shale, sandstone, and limestone. (Figure 6).

Structure

Bandera County can be classified as a south-southeastward dipping monocline which is crossed by discontinuous northeastward-trending faults and folds of the Balcones fault zone. There is also a minor system of synclines and anticlines with strikes generally north-south across the county, their axes gently plunging southward nearly at right angles to the Balcones fault zone.

The regional dip of rocks is to the southeast from 10 to 20 feet per mile. In the southeastern part of the county the dip steepens to about 100 feet per mile and is chiefly toward the south.



The faults of Bandera County are not continuous for long distances and the strike is northeastward. These are normal faults with steep dips to the southeast at angles of 65° to 78°. They are downthrown to the southeast, the maximum throw on a single fault is about 100 feet, all of which is fairly typical of the Balcones displacements in this area.

Folding in the county occurs in two trends, which have developed the drainage system of the county. The major trend is flexures which are parallel with the Balcones fault zone; The strikes being northeastward.

The Glen Rose limestone is recharged through fissures and alluvium by the streams on the exposed surfaces and by the direct filtration of rain. Sometimes the streams serve both as a recharge and discharge facility for the Glen Rose. The water may enter porous or fractured zones upstream and then discharge the water downstream where the stream bed intersects the water table. Most of the ground water in the Glen Rose occurs under artesian pressure because of the presence of the shale beds which act as confining layers for the beds of limestone.

History

In the early spring of 1853, three families came to Bandera County and camped on the Medina River, where they engaged in making cypress shingles. A horsepowered sawmill was established, a commissary store was built, two or three cabins were erected, and the settlement became a village which was called Bandera. "Bandera" in Spanish means banner. A firm by the name of James Montel, & Co. plotted the townsite of Bandera in 1853. Bandera Pass is a noted gap in the chain of mountains about ten miles north of Bandera on what is now Texas Highway 173. This pass was named for General Bandera, a Spaniard, who in 1733 defeated a large number of Apaches, who made these mountains their rendezvous for attacks on the Spanish missionaries around San Antonio.

Several battles were fought at Bandera Pass, the most noteworthy being the desperate fight there in 1843 when Col. Jack Hays and his rangers defeated a large party of Comanches. In this fight the Indian chief was killed and his grave is said to be at the north end of the pass.

On March 1, 1854 Elder Lyman Wight's company of Mormons, numbering about 250 people, reached Bandera. After a few years they moved several miles below Bandera and established a camp on the Medina River. Several years later when Elder Wight died the colony was disbanded.

In 1855 a Polish colony of 16 families were persuaded to settle in Bandera. Today a large percentage of Bandera's population is made up of decendants of these early Polish settlers.

Bandera County was originally part of Bexar County. On March 10, 1856 the separate County of Bandera was created by an act of the Texas Legislature. Shortly thereafter the populace elected a sheriff, tax assesor and other officers.

Just three miles north of Bandera Pass on Verde Creek in Kerr County lies Camp Verde. It was established in 1856 as a camel post for frontier protection. The idea of using camels for transportation on the Texas frontier was fostered by Jefferson Davis, who persuaded Congress to pass the act establishing Camp Verde. Despite the eighty camels and twelve expert Armenian camel drivers brought here, the experiment was a failure. The soft, spongy feet of the camels prevented their use in these hills. The camels frightened the horses and were very ill-tempered. After a ten year trial the camels were sold by the government.

At the age of 14 Charles Montague, Jr. came to Bandera with his father in 1859. After the Civil War, during which he served in the Confederate Army, he went to New York. When his health was failing he returned to Bandera where he resided until his death on April 25, 1916. During the years he lived there he was one of the most useful and honored citizens of the County. In 1872 he was elected by the office of District and County Clerk, where he served fourteen consecutive terms. He was admitted to the bar and for years was regarded as the most able attorney in this section of the state. He later became judge of Bandera County. Frank M. Montague lived on the ranch established by his grandfather, Charles Montague, Sr. The family has occupied the present homestead since 1880.

The town of Bandera is underlain by the Glen Rose limestone whose rock was used to build the Catholic Church and school, the courthouse and the public school. The Catholic Church was built by the Polish colonists around 1855 and is still in use today as are the public school and the courthouse.

To the south-southwest of Bandera in Medina County lies the Medina Lake Dam, completed November 24, 1912. The natural break in terrain as the Medina crosses from Edwards Plateau to Coastal Plain seemed a natural spot for an irrigation dam in the fertile lower valley of the Medina. However, due to a lack of interest the project was not given more than a passing thought.

In 1910, Dr. Fred Pearson, an entrepeneur of the type so common in the new west, sold bonds under the name of the San Antonio Land and Irrigation company amounting to $6,000,000.00.

The Medina Irrigation Corporation, with offices in San Antonio, was the agency which built the dam, using solid concrete with very little reinforcing steel. The dam and canal systems are still in use, both for irrigation and recreation purposes.

Upon completion, the Medina Dam was the largest in Texas, and the fourth largest in the United States. Its height is 164 feet above the bed of the Medina River. Its overall width at the base is 128 feet; at the top, 25 feet, 16 feet of which is used as a narrow roadway. The length of the dam at the crest is 1580 feet. Medina lake covers an area of 5575 acres at spillway level, and 6260 acres at flood stage. The length of the lake is about 18 miles, and the maximum width is about three miles.

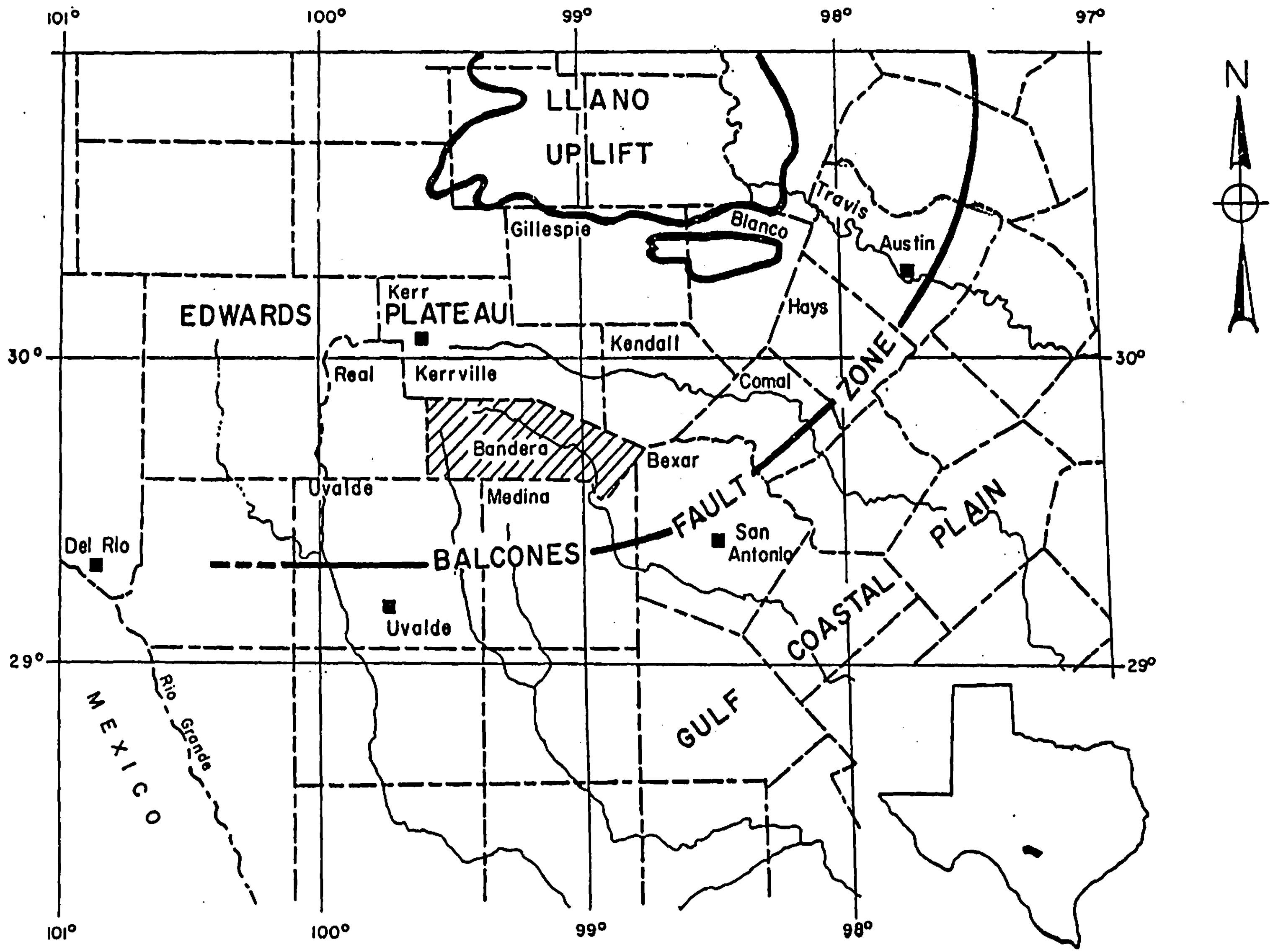
This source of water was intended to be used to irrigate 60,000 to 150,000 acres of farmland as far as 25 to 30 miles away. For some reason from the very beginning, the water supply was apparently over-estimated. Due to the lack of knowledge of geology of Bandera County, the builders of Medina Dam built a reservoir that is famous for its vascillating water level. Although it does overflow at times, most often the level goes down to zero. The reason for this is that the Medina, in southern Bandera County, crosses a recharge area full of joints and sinks. The watersheds' loss is the aquifers' gain, so it wasn't such a bad deal after all.

References

Hunter, J. Marvin. Pioneer History of Bandera County, Bandera, Texas. Hunter's Printing House. 1922.

Kuehne, S. M., The Reverend Cyrill Matthew. Ripples From Medina Lake. San Antonio, The Naylor Co., 1966.

Ibid; Keuhne.



101°
100°
99°
98°
97°
N
LLANO
UPLIFT
Travis
Blanco
Gillespie
Austin
Kerr
EDWARDS
PLATEAU
Hays
Kendall
30°
Real
Kerrville
Comal
ZONE
Bandera
Bexar
Uvalde
Medina
FAULT
PLAIN
San
Antonio
Del Rio
BALCONES
Uvalde
COASTAL
29°
MEXICO
Rio Grande
GULF

Figure 5

GENERAL SECTION OF GLENROSE IN BANDERA COUNTY

GLENROSE (UPPER)

MANY COLLAPSED STRUCTURES

SOME SIGNS OF EROSION PRIOR TO DEPOSITION OF EDWARDS

(EVAPORITE)

(BLUE THIN MARLY MEMBERS)

(EVAPORITE)

Orbitolina texana — Exogyra texana

Lopistha, Arca — Tylostoma, Nerinea

Monopleura — Toucasia, Pteria

Corbula

GLENROSE (LOWER)

Salenia texana — Trigonia

Orbitolina texana

Hemiaster

Porocystis — Douvilliceras

Rudistids

(NODULAR LIMEY MARL)

Orbitolina texana

(MASSIVE LIMESTONE)

MARL MEMBERS

Rudistids

Figure 6

FLINT NODULES AND RUDISTIDS

Robert Bippert

"The Edwards limestone, of upper Middle Albian age, is the only Cretaceous limestone in the Texas region which contains appreciable amounts of chert".[1] From personal observation, it has been noted in many places around the Balcones Curve, that chert nodules occur just above the rudistid reefs.

Chert and limestone nodular development has some dependence upon reef development. Silica occurs in the Edwards in the form of chert nodules which occur parallel to bedding planes. These beds have an interrelationship with the rudistid reefs, in that they intermingle and overlie the reefs with some consistency. Many of the chert and limestone nodules were found to contain sponge spicules.

The reef rocks are made up of the remains of the pelecypod known as the rudistid (the name implying a type of skeletal form rather than a genus.) The reefs are characterized by marine bedding and the abundance of reef organisms. Dolomitized limestone usually underlies the rudistid reefs. The reefs were built either on this dolomite (which was then in the form of lime mud) or actual anticlinal highs, growing upward as the depth of the enveloping water increased. Nelson

(1959) suggested that the rudistid reefs grew in water less than thirty feet deep in the zone of wave action; certain reefs, he thought, grew up to sea level. The rudistid reefs resulted in the deposition of the rudistid lithosome, apparently acting as an energy barrier. Their abrupt extinction is more difficult to explain since in this region deposition of calcareous sediment continued uninterrupted.[2]

Environment of Deposition

During the upper Middle Albian, the sea transgressed a large portion of Texas with the exception of the Panhandle. Texas had a few topographical highs. The Llano Uplift was a topographic island in the center of the state. Organic evidence points to the sea's being shallow and warm at this time, permitting an excellent environment for extensive organic growth.

It is thought that sponges and other organisms gathered silica from the seawater and that, after death, this silica dissolved in some places and precipitated in others as a result of differentiation in the pH factor in the seawater. Preserved fossils and many carbonate fragments within the nodules proves the replacements. Since the diffused silica in the seawater is almost impossible to precipitate by inorganic means, organic agents must be responsible for the replacement origin of chert. Preserved fossils and many carbonate fragments within the nodules also promotes this theory.[3] According to Krumbein and Sloss,[4] silica is deposited in conditions of neutral pH (7) and high salinity. Deposition occured at places where these conditions were met and at other places (of high pH) where solution presented deposition. No other organisms than sponges can be found that could have created such large quantities of silica as found in the Edwards in the form of the chert nodule.

The history of the relationship between the rudistid reef and the chert nodules is that the limestone was laid down first (and later subjected to dolomitization), rudistids grew on top of that and silica gel formed blobby deposits in the top of the reef at isolated places where high pH prevailed. Upon uplift, the whole area was lithified. Dating of the lithification of the chert nodules before lithification of the surrounding limestone is determined by the fact that the chert nodules cracked and the cracks filled with what was then lime mud.

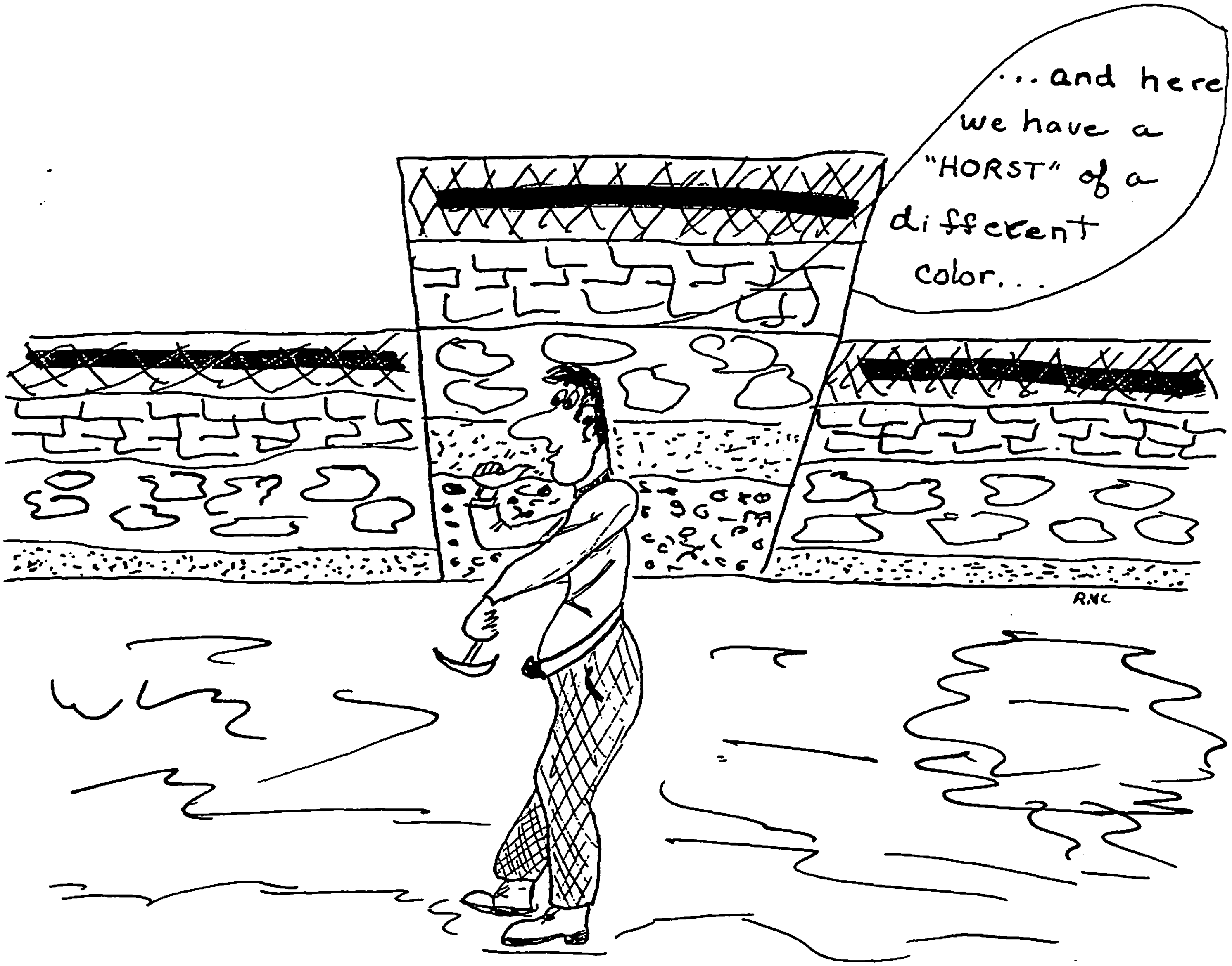
References

1. Pittman, J.S. Jr., Silica in Sediments, Society of Economic Petrologists and Minerologists, Tulsa, pp. 121.

2. Moore, R.C., Editor, Manual of Invertebrate Paleontology, Vol. 6, Mollusca, Part N., pp. N764.

3. Ibid; Pittman.

4. Krumbein and Sloss, Stratigraphy and Sedimentation, 1963, Freeman, pp. 221.



FLORA AND FAUNA OF THE TRIP AREA

Harcourt Newman

Our field trip lies within the Edwards plateau vegetative area and on the southeastern limit of the Balconian Biotic Province adjacent to the Texan and Tamaulipan Province. The area adjacent to the Cascade Cavern entrance and the karst chimney is best described as a juniper and oak savannah.

Some of the trees adjacent to the Cascade cave entrance have been marked with signs such as Quercus virginius, which it is believed should be Quercus fusiformis. Juniperus ashei is well represented from the dominant scrubby form to a few specimen trees of 30 feet with sufficient loose bark to attract the rare Yellow-Cheeked Warbler that is known to nest in mature Juniper stands in the Balconian area. The Ashe Juniper or "cedar" (Juniperus ashei Buchholz) is an extremely hardy tree that has, and still is, replacing the extensive grasslands that were in this area. The spread of Juniper follows overgrazing by cattle and sheep. Once this encroachment, or succession, has started, there is little to stop it as it is so well adapted for competition in this semi-arid region. The root system has two types, deep roots find their way between rocks and joints to the deep sub-surface water and can thus withstand drought conditions. A network of roots is then begun parallel to the surface, depleting the area of moisture and nutrients, acidizing the soil and making growth difficult for other natural flora accustomed to alkali. The seeds are contained in blue berries that ripen from September through late fall. The fruit is eaten by a variety of birds and animals. Quail, turkeys, raccoon, deer, and others relish the abundant fruit, the seeds passing through the digestive tract and being deposited with their own fertilizer supply.

The "cedar" wood is durable for fence posts, has little value for construction, but makes good firewood. Deer and goats will browse new cedar shoots but cattle will not. Many ranchers are now cutting out the juniper and leaving the liveoaks in hope that the oaks will provide shade and hold the soil until a new grassland can be established, but it often follows that catclaw and Opuntia take over the biota instead.

There are several oaks in the field trip area, among them Quercus texana and Quercus virginiana variety fusiformis. These two varieties are indigenous to limey soil. Many more varieties are found where soil is sandy (i.e. redoaks, pinoaks, jackoaks, blackoaks). The wood from the trees growing on the plateau is splintery and brittle but provide firewood for many a barbecue. The "Texas liveoak" (Quericus texana) in this area is in trouble. What is called by Texas A and M's Dr. Halliwell as Live Oak Decline is a fungus disease fatal to the liveoak wherein the redoak is the intermediate host.

Mesquites (Prosopis juliflora) have always been associated with Texas in song and story. They are found on the plateau but prefer the sandier moister soil of the coastal plain and therefore serve as a topographic and geologic marker. Mesquite beans were a good source of food for Indians and cattle and would serve a stranded man food in the wilds of South Texas. The wood is incredibly hard and elastic and made excellent Apache bows as well as wheel spokes for pioneers. Gum Arabic is made from the sap and is used as an adhesive and in the making of porcelain.

This country is a curious mixture of thorny desert plants and soft water plants. One of the former is Opuntia, the prickly pear which is mostly a curse transported from Mexico by fecal matter of trail-driven cattle. It can, in dry years, prove a blessing as ranchers buy U. S. Government issue flame throwers to burn "pear" thorns off so the cattle can forage on the succulent meat. Other thorny (also secondary) growths are catclaw and holly (Algerita) which have turned some cleared land into impassable wildernesses.

Near the water courses one finds a surprising amount of ferns such as Anemia mexicana and maidenhair (Adiantum), watercress, Chara, a limestone depositing thallophyte, and cattails.

Much of the plateau was grassland and silky buffalo grass will return in about 7 years to cutover land if Opuntia and catclaw are kept at bay. Southern Bermuda grass is found on many slopes. St. Augustine grass does well (for an import) in protected places.

The following is a list of some of the flora and fauna of the area:

Mammals

Armadillo (Dasypus novemcinctus)

Bats (Tadarida brasilensis mexicana) Mexican free-tailed bat
(Myotis velifer)
(Myotis lucifugus)

Coyote (Canis latrans)

Deer (Odocoileus virginianus texanus) Texas white-tailed deer

Opossum (Didelphis marsupialis)

Rabbit (Sylvilagus floridanus) Cottontail
(Lepus californicus) Jackrabbit

Raccoon (Procyon lotor)

Birds

Dove (Zenaidura macroura) Mourning dove

Grackle (Cassidix mexicanus) Brown grackle

Quail (Colinus virginianus) Bob white

Piasano (Geococcyx californianus) Road runner

Sparrow (Amphispiza bilineata) Black-throat
(Chondestes grammacus) Lark
(Passer domesticus) House

Swallow (Petrochelidon pyrrhonota) Cliff swallow

Vulture (Coragyps atratus) Black

Warbler (Dendroica chrysoparia)

Amphibians

Frog (Rana pipiens berlandieri) Leopard frog
(Acris crepitanus) Cricket frog

Fish*

Mosquite fish (Gambusia affinis)

*A list of game fish may be found in any fishing guide.

Reptiles

Snakes (Crotalus atrol) Diamondback rattler
(Leptotyphlops dulcis) Texas blind snake
(Pituophis melanoleucus) Bullsnake
(Lampropethis blairi) Texas kingsnake

(Micrurus fulvius tenere) Texas coral snake
(Agkistrodon contortrix lacticinctus) Copper head
(Thamnophis sauritus proximus) Ribbon snake

Trees

Acacia (Acicia farnesiana) Huisache

Ashe juniper (Juniperus ashei Buchholtz) most abundant cedar on the plateau

Elm (Ulmus crassifolia) Cedar Elm

Hackberry (Celtis sp.)

Holly (Berberis trifoliolata)

Mesquite (Prosopis glandulosa)

Oak (Quercus fusiformis) ...a liveoak but of a different variety than that in sandy soil
(Quercus texana) indigenous to the plateau
(Quercus shumardii) redoak

Persimmon (Diospyros)

Shrubs and Wild Flowers

French mulberry or Beauty berry (Callicarpa americana) a magenta colored berry plant found growing over the entrance to Cascade Caverns

Turk's cap (Malvaviscus drummondi) Mexican apple or Red Mallow...a 9 foot perennial

Bromelaids or Spanish moss (Tillandsia usneoides) an airplant or epiphyte. Airplants whose young forms exist on embryonic energy until their hair-like roots trap enough humus for their needs.

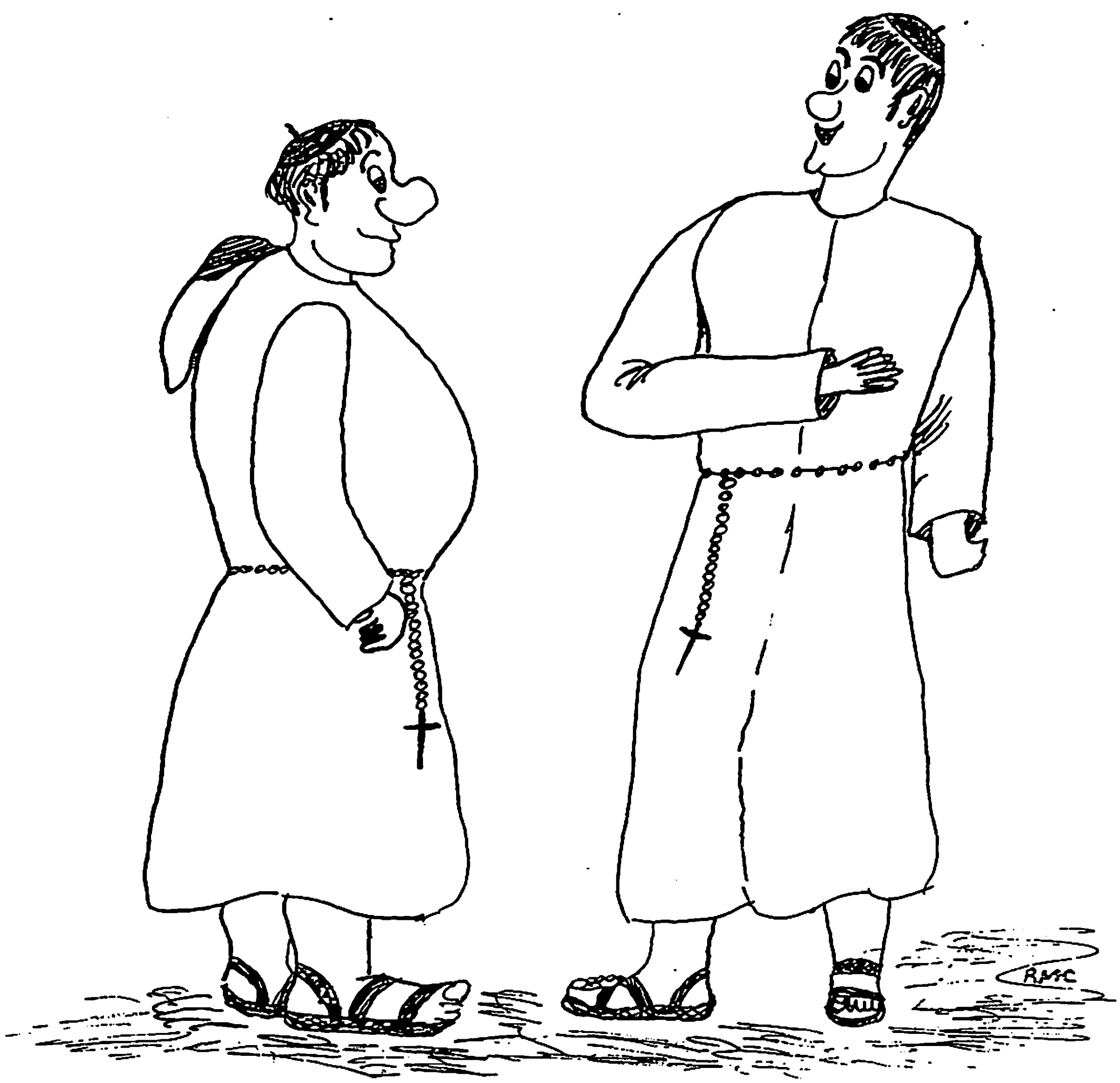
References

Dewers, R. S., How to Save Those Dying Live Oaks, Express/News, November 18, 1972. Express Publishing Co., San Antonio.

Peattie, D. C. A Natural History of Western Trees, Houghton Mifflin Co.,Boston, Mass. 1953.

Sargent, Chas., Manual of the Trees of North America, Houghton Mifflin Co., Cambridge, Mass., 1933.

Vines, Robert A. Trees, Shrubs and Woody Vines of the Southwest. University of Texas Press. 1960.



"... At least Science hasn't quit using Latin."

CAVERNS OF SONORA

John Price

A small opening in the Mayfield Ranch (Sutton County) was explored in 1900. After much blasting and paving work and wiring was done, the site became the Caverns of Sonora,[1] and was opened to the public in 1960. The caverns are presently owned by a corporation whose directors include the original owner, Stanley Mayfield, and nine Sonora businessmen. This business-like organization is not in the least interested in encouraging research by scientists and the employees tend to be surly and ill-informed. The caverns are well worth seeing, however, and are unique in many ways.

The caverns have five levels, each with slightly different conditions of humidity and temperature. The upper level is almost free of speleothems and the tourist has a distinct feeling of warmth and scarcity of oxygen. The deeper one descends the more the humidity and atmospheric conditions seem like usual caves, with a year round temperature of 70^{o}.

The cave formations known as helictites and coralloids are those most typical of Sonora. The helictites, according to a theory promoted by G. P. Merrill in 1894[2], have a narrow central canal along the axis, feeding water toward the tip in vapor form, the result being a cone formed of one crystal which, because of the irregularities of the calcite scalenehedron and (in the case of Sonora) the gypsum crystal form,[3] does not set directly on the previous crystal but slightly lopsided, like an errant dunce cap. This leads to the curious curving of helictites noted in tourist guides as "defying gravity." The existence of water in vapor form and the tiny capillary spaces are probably the result of scarcity of ground water and the massive nature of the limestone here in this southwestern corner of Texas. These helictites with their little cones visible under low-power magnification, cover floor, walls, and ceiling of the third level. In the clustered arrangement, they are called coralloids.

Sonora caverns have been eroded in the Edwards and Upper Glen Rose, the latter having some fairly thick evaporite members. The Edwards in Sutton County is massive and the Glen Rose seems to have more capillary spaces than the Glen Rose further east.

References

1. Texas Caver, November, 1961 (Insert from Electric Times, October, 1961), p. 126.

2. Moore, G. W. , and Nicholas, Bro. G., Speleology, D. C. Heath & Co., 1964, p. 47.

3. Ellis, Wm. G., personal interview.

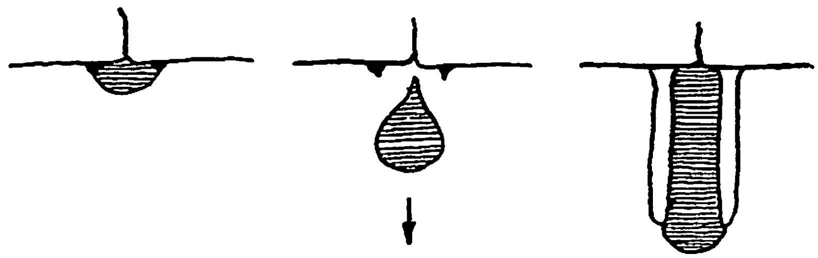
CAVE FORMATIONS (Speleothems)

Deborah Ann St. Clair

Cave water is slightly acidic in the summer and slightly alkaline in the winter. Also, the carbon dioxide content of cave air is highest in the summer. These annual fluctuations result from seasonal variations in the production of carbon dioxide by micro-organisms in the soil. Limestone is dissolved at the base of the soil zone in water rendered acidic by dissolved carbon dioxide and is deposited again when the soil water migrates downward into the cave encountering the relatively low carbon dioxide content of the cave atmosphere. Deposition of calcite on speleothems is dependant upon loss of CO_2. Fluctuations in the growth of speleothems is related to fluctuations in the percent of CO_2 in the ground water.

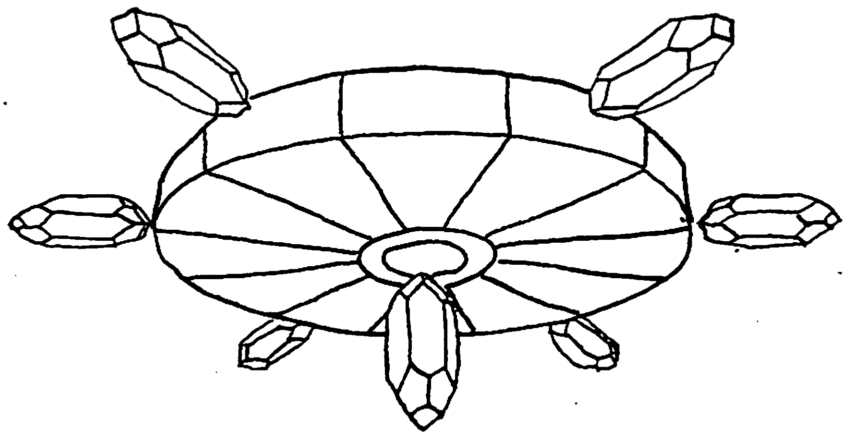
<u>Stalactites</u>:

Water seeps from a crack or joint in the ceiling of a cave. In caves that are sufficiently ventilated, the carbon dioxide will evaporate from a water droplet, leaving a ring of calcite, forming tubular stalactites. This tubular stalactite is usually formed of only one calcite crystal. As a drop of water deposits calcite, the molecules will rearrange themselves according to the preestablished molecular structure.



Water dripping from the tip of a stalactite deposits a central cylinder with vertical crystal orientation, whereas water flowing down the sides deposits radiating crystals. Thus it appears the same as if it had been carved from one large calcite crystal. Even the huge stalactites one may see in a cave were originally a small tubular stalactite. Proof of this is found in a stalactite that is broken. It will have a quarter-inch tube of pure calcite in the center showing where the original tube had been.

Many studies have been made trying to establish some type of growth rate for speleothems. However, the greatest difficulty arises in the unique conditions in each cave which affect growth. Whatever a scientist may find under a controlled experiment will not necessarily be the same for all caves. Concrete structures with stalactites growing from them have repeatedly given a false notion of the growth rate of cave stalactites, but radiocarbon dating, actual measurements in caves, and study of annual growth increments show that the rate of elongation, though variable, averages about a quarter of a millimeter per year. The outer layers of the huge conical stalactites are formed by flowing water as opposed to dripping water. These deposits of calcium carbonate form parallel to the surface and are most abundant at the top of the formation tapering downward. The crystalline structure of the outer layers differs from that of the central tube. These crystals grow outward. The polygonal bases of these



outer crystals may be as large as one inch in diameter and sparkle when light is shone across them.

Draperies:

Draperies are thin, translucent sheets of calcite formed by a drop of water flowing downward along an inclined ceiling, leaving behind it a trail of calcite. This gradually builds up to form sheets ten feet or longer. Impurities such as iron leave streaks colored red, orange, and brown and are often referred to as bacon.

Stalagmites:

Stalagmites are the counterparts of stalactites. Speleothems is the general term for all cave deposits. A good method of remembering the two major types of speleothems is by use of the "memory crutch"; "Stalactites hang tight to the ceiling, but stalagmites might someday reach the ceiling." When a drop of water falls from a stalactite, it retains some of the carbon dioxide. As it hits the stalagmite, the shock breaks up the drop, drives off the gas, and the calcite is thrown off thereby contributing to the growth of the stalagmite. Stalagmites tend to be larger in diameter than stalactites and have rounded tops rather than the pointed tips. A stalagmite and a stalactite that grow together form a column. Flat-topped stalagmites (fried eggs) are usually found in dome pits. Drops falling from great heights usually form a series of offset plates averaging about an inch in thickness and eight inches in diameter. The crystal structure of a stalagmite is radial, consisting of many crystals perpendicular to the surface of growth.

Flowstone:

Water flowing down the walls of a cave form flowstone. The crystals can be seen in the way they sparkle. Rimstone dams are made of a series of steps which hold cresent-shaped pools. As the water flows over the edge of the dam it is slightly agitated and carbon dioxide is given off resulting in the deposition of calcium carbonate on the rim.

Helectites:

One of the best known deposits formed by seeping water is a helectite. A canal extending along the helectite axis conducts water under hydrostatic pressure from a minute hole in the cave wall to the tip. The flow of water is so slow that no drop forms at the tip and gravity is not able to affect its shape.

Cave Coral:

Cave coral, or popcorn, is another common deposit. They are knobby clusters in which the radiating crystals are perpendicular to the growth band. In cross-section there is a concentric banded structure. It occurs mainly along cracks in the wall or on porous cave silt. Because there is no central canal, it is believed that they form by the seepage of water between the crystals.

Cave Pearls:

Cave pearls are fairly rare in cave deposits. They can vary in size from small as the head of a pin to some as much as 6 inches in diameter. They form around a nucleus of a grain of sand or even another piece of speleothem. Constant agitation, rotation and dripping or splashing is necessary. The crystals of calcite grow perpendicular to the surface of growth.

References

Moore, George W., The Growth of Stalactites. National Speleological Society Bulletin., 24 (2), 1962., pp., 95-106.

Moore, G. W. and Bro. G. Nicholas F.S.C., Speleology, The Study of Caves. D. C. Heath and Company, Boston, 1964.