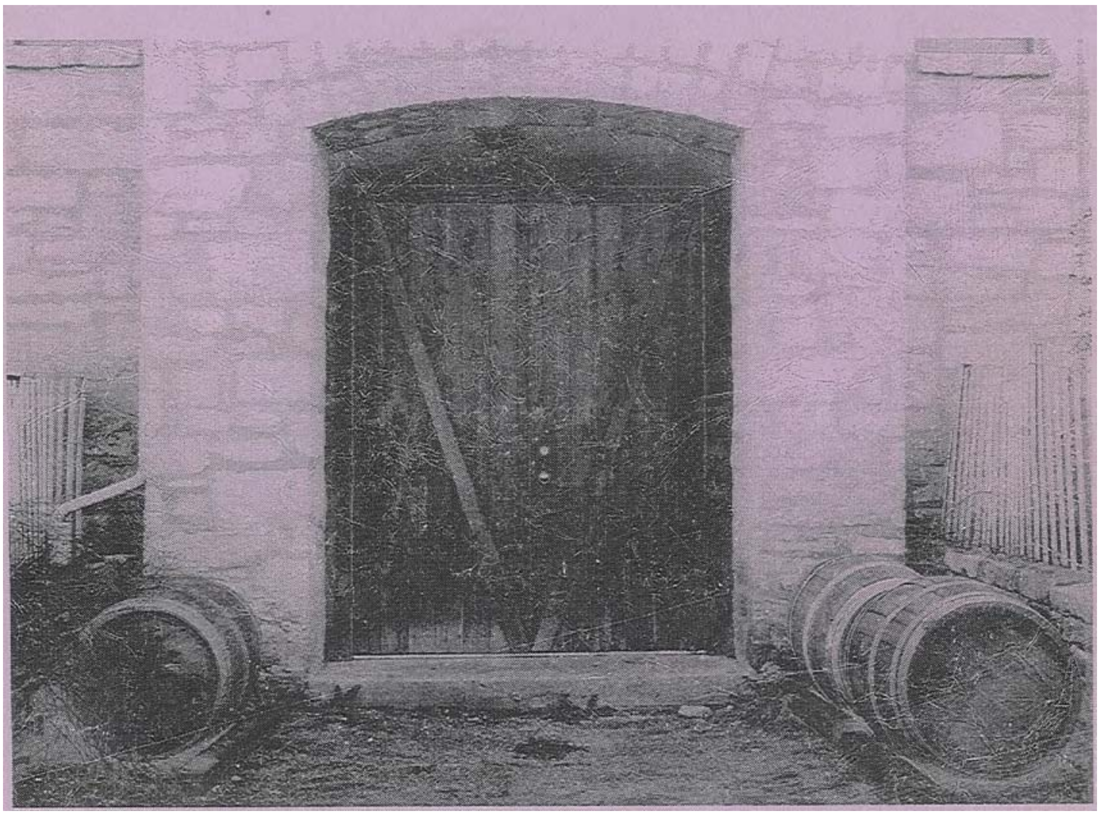
THE HILL COUNTRY APPELLATION

A Geologic Tour of Selected Vineyards and Wineries of Central Texas

C.M. Woodruff, Jr., Peter R. Rose, and James W. Sansom, Jr.



GUIDEBOOK 18

Austin Geological Society
P.O. Box 1302
Austin, Texas

March 28, 1998

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"The sun, with all those planets revolving around it and dependent on it, can still ripen a bunch of grapes as if it had nothing else in the universe to do."

Galileo

"The relation between maps and wine is a very intimate one. Wine is, after all, the unique agricultural product whose price depends entirely on where it comes from. The better the wine, the more exactly it locates its origin--down, eventually, to one diminutive field..."

Hugh Johnson
The World Atlas of Wine
(Fourth Edition, 1994)

Cover Illustration: Spicewood Vineyards, Spicewood, Texas.
Photograph by Robert W. Baumgardner

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FOREWORD

This field trip has predecessors that date back to 1992. At that time a trip was led for the Austin Chapter of the Society of Independent Professional Earth Scientists (SIPES), the first field trip to explore the common ground between geology and wine in Central Texas. The accompanying guidebook (Rose and Woodruff, 1992) gave special attention to historical sites and events along the route. Similar trips were run for the 1994 meeting of the Gulf Coast Association of Geologic Societies, and in 1997 for the 34th Annual Meeting of SIPES; the guidebooks produced were variations of the 1992 version (Rose and Woodruff, 1994; 1997).

Today's trip visits an entirely different set of wineries, and this guidebook has taken a different tack, with greater emphasis on geology and less on history. However, this guidebook has retained key papers from the previous volumes.

The guidebook is arranged in the following way: After the short topical papers, a road log presents the route taken and various geologic, geographic, and historical notes along the way. Using this log, the route may be retraced via automobile. At the end of the road log are brief discussions of the geologic and pedologic settings of the vineyards at each of the four wineries visited. Following the site discussions is a single compilation of references cited throughout the guidebook. And at the end of the book are appendices that include a guide to key wine terms and techniques of wine-tasting, blank "tasting forms," and on the last page, names and addresses of contributors to this book and addresses and telephone numbers of the four wineries.

Acknowledgments

We are indebted to the owners and operators of the wineries visited today. We thank them for their courtesies and warm hospitality--both on the day of the trip and during previous visits when the trip was being developed. These men and women are pioneers; they are on the frontiers of knowledge, and they have incurred significant financial risk. They exemplify the courage and determination typical of the Texas pioneer spirit, and we salute them.

We are grateful to Robert W. Baumgardner for the photograph that he generously provided for the cover of this guidebook. We also are indebted to geologist and ex-Shell Vice President, James E. Wilson, for kind permission to include his article on <u>terroir</u>, which is an excerpt from his book, <u>Wine on the Rocks</u>. We also thank Elizabeth Ethridge for her organizational (and computer) skills in keeping track of the various versions of manuscripts dealing with wines and geology. And we thank AGS President, Patricia Bobeck, for administrative support.

Charles Woodruff, Jr.
Peter R. Rose
James W. Sansom, Jr.
Austin, Texas
March 1998

THE HILL COUNTRY APPELLATION
Common Ground Between Geology and Wine in Central Texas

C. M. Woodruff, Jr.

This field trip may seem to be an unconventional geologic excursion, but there is much logic behind it--beyond the sheer pleasure of tasting local wines and enjoying a bus tour of splendid Hill Country scenery. The rationale goes literally to the root of the nascent wine industry of Central Texas. As with any vascular land plant, the roots of the grape vine extract water and nutrients from the soil zone to sustain the plant. The uptake of soil moisture is of special importance to a fruit-bearing plant such as Vitis vinifera, the wine grape. Clearly, wine is fermented juice of the grape. And as succinctly noted by Johnson (1994), "Every drop of wine is rain recovered from the ground by the mechanism of the grape-bearing plant..." With this in mind, one can readily appreciate the connection between geology and the growing of grapes.

Geologists are trained in recognizing the great diversity of substrate materials and the constructional and destructional processes that act on Earth materials to create and alter soils, landforms, sediments, and rocks as the Earth evolves through time. Geologists also are generally familiar with the hydrologic cycle as a key nexus of processes acting at and near the Earth's surface. This cycle includes the fate of rainwater on the land--the routing of incident rain through the circuits and buffers within soils and substrates to produce, from place to place, varying amounts of runoff, recharge, and evapotranspiration. This knowledge of Earth materials and the cycling of waters thus provides the connection between the professional concerns of the geologist and those of the grower of grapes and the producer of wines.

The near-infinite site-by-site permutations between bedrock, soil, landform (including relief, slope, position on slope, and slope aspect), micro-climates associated with the varied slope conditions, and the overall prevailing climate, as well as local weather (which, of course, changes day-by-day)--all combine to impart distinctive characteristics to a vine's fruit, and to the bottled product. Further complicating the issue are the varietals, the many different kinds of grape that may respond quite differently to the complexities of substrate and soil and slope. The French have a word for the subtle, but inalienable, influences of the ground on the grape. That word is *terroir*, which roughly translates to the English cognate, terrain. But it means more, and it eludes exact translation. It certainly includes cultivation, which in the great vineyards of France has involved centuries of husbandry. The implications of this word are discussed in this guidebook by Peter R. Rose and by James E. Wilson. Suffice it to say that the variables that contribute to the qualities of wine are many, and in the end, reductionist science can never analyze nor fully understand what makes a great wine.

The rise of Central Texas as a commercial wine-producing area dates back only to the mid-1970's. But notwithstanding this recent emergence of the region, Texas has a long historical wine-making tradition that goes back to the pioneer German and Alsatian settlers, who produced wine mainly for family consumption. And even in the Twentieth Century, wines were produced commercially in Texas, with more than a score of wineries in 1920 (Johnson, 1994). But prohibition killed the industry, and it took special action of the State Legislature in 1977 to allow the reemergence of viticulture and wine making in Texas.

Texas, however, possesses an even more fundamental grape-growing tradition: As noted by Johnson (1994), the state's size and expanse of ecological niches has resulted in Texas truly being America's "Vinland." Of the 36 species of the genus Vitis known world-wide, 15 are native to this state. And as discussed herein by Rose, a Texas-native variety of Mustang grape provided the disease-resistant root stock that saved the European vineyards from the phylloxera epidemic in the late Nineteenth Century.

Today, the Central Texas Hill Country is denoted as a distinct American Viticultural Area (AVA), which in America, is the formal appellation of origin. The Hill Country, however, is a vernacular name, and its boundaries are a bit fuzzy (see discussion by Woodruff, 1997). As a geologic province, it is the dissected area between the Balcones Escarpment and the continuous uplands of the Edwards Plateau. In the public mind, the Llano Uplift is generally considered to be part of the Hill Country, although most geologists probably make a distinction between the limestone Hill Country (mostly on Cretaceous rocks), and the Llano Country with its complex terrains consisting of Precambrian and Paleozoic rocks.

The Hill Country Appellation includes sites on Paleozoic, Mesozoic, and Cenozoic rocks and sediments. At this writing, I know of no vineyards sited on Precambrian rocks, although there is no constraining reason for this. However, I cavil at inclusion of one vineyard within this AVA located southeast of San Antonio, a site east of the Balcones Escarpment. As professionals, we should take a stand in educating the public that the "Hill Country" does not extend east of the Escarpment. But alas, unfortunate precedents exist. For example, the University of Texas at Austin "FACTS" brochure for 1996-1997, describes the campus as "40 acres near the state capitol in the heart of the scenic Central Texas Hill Country."

This field excursion tours the true Hill Country, a region characterized by limestone uplands cut by streams and rivers of various sizes. Local occurrences of sandstone and shale occur where the basal part of the Cretaceous section is exposed, and elsewhere within the Hill Country Appellation are the Precambrian granites and metasediments and the fault-bound Paleozoic sedimentary rocks. As will be discussed herein, vineyards visited during this excursion present a diversity in terms of geologic substrate--one of the fundamental controls on the multi-faceted *terroir* concept.

As we traverse this region, we will note first-hand the varied influence of hydrologic processes on the landscape. We begin our trip on U.T. campus at an elevation of just under 600 ft above mean sea level; we cross the Balcones Escarpment at about 800 ft elevation, and we reach a maximum elevation just shy of 2,000 ft. All but one of the wineries visited today lie at elevations above 1,000 ft. All but one of these wineries lie west of the 98th Meridian. And all but one are situated north of the 30th Parallel. We can note the effects of altitude and cartographic position on the grapes and the wines produced. These factors combine with substrates and soils and slopes as key elements of *terroir*. In time, the subtle effects of soil and microclimate and landform--all with probable geologic controls-- will be better understood as the vintners apply their arts and sciences and respond to trial and error and, it is hoped, to success!

FRONTIER HISTORY AND WINE

Peter R. Rose

It would be fitting, somehow, if the existence today in Central Texas of significant commercial wineries could truly be laid to the cultural traditions of the German immigrants who came there 150 years ago. Although the German settlers did, in fact, have intimate knowledge and appreciation of the vineyard and of wine making, they appear to have directed their oenological efforts mostly toward supplying their own family and community needs, rather than for the commercial market.

Gilbert Jordan, whose grandparents were German immigrants who settled in Mason County recites (1979) his father's recipe for making wine:

> *Crush the ripe grapes by pounding them with a wooden plunger in a tub. Pour the crushed mass into an upright barrel until it is three-fourths full. Now place clean cloth on top and cover the barrel with the lid. A hole must be drilled on one side as close to the bottom as possible and closed with a removable plug. Fermentation will be finished in two to four days. Now tilt the barrel so that the juice will pour into the tub when the plug is removed. Strain out the seeds and hulls and pour the juice into a forty-four gallon fermentation barrel that is lying horizontally. Pour twenty-two gallons of the new-wine juice into the barrel and add eighty-eight pounds of sugar. To obtain additions for pouring later, take seventeen to eighteen gallons of water, dissolve one-third or one-half of the eighty-eight pounds of sugar in it, pour this sugar-water into the grape residue left in the first barrel, and stir thoroughly. Repeat fermentation and pouring as above. Then add the rest of the sugar, stir thoroughly, and pour this juice into the barrel, until it is full.*
>
> *Now the main fermentation will begin, and it will take several weeks. Keep the barrel full to overflowing by adding the remaining juice. Leave the hole open and add juice as long as any waste is expelled. After ten to twelve days, the entry of air should be prevented but the gasses still permitted to escape. Only after the completion of fermentation should the hole be closed. To make possible the escape of the carbon dioxide without the entry of air and vinegar germs, insert a small U-tube and immerse the outside end in water. Around Christmastime, put the wine in another barrel. It will ferment again in spring and turn slightly brown. Then it should be drained off into another barrel or into bottles for storing.*

But, in fact, the establishment of commercial wineries in the Llano Uplift area is a relatively recent business development, a regional expression of the developing American interest in wine and wine making. There is no long-standing tradition, European or otherwise, from which this spate of Central Texas wineries sprang. One reason, of course, is that wine was not a strong or even significant aspect of the Scotch-Irish culture which dominated the region's history of settlement -- the Scotch-Irish preferred whiskey, and beer, which the Germans knew even more about than wine! Books by Giordano (1984) and English (1989) describe modern wineries in Texas.

For that reason it is ironic that a Scotch-Irish Texan -- Thomas V. Munson -- played a major role in saving the wine industry of France, using primarily native Texas mustang grape root stock. All this transpired during the 1880's -- toward the end of the frontier period described here.

As described by McClurg (1977) the 18th and 19th century French vineyards consisted almost entirely of *Vitis vinifera* rootstock. About 1870, *Phylloxera vastatrix*, a plant louse, was accidentally introduced into Southern France from the United States. The pest attacked the native French rootstock, spreading steadily northward with devastating results. The French vineyards were decimated, with serious economic repercussions affecting France, and indeed, much of Western Europe as well. The economic loss to France alone has been estimated at approximately $2 billion, a staggering sum in the 1880's.

The American native grape rootstock was *Vitis labrusca*, which was resistant to *Phylloxera*. And Thomas Munson, who established and operated a thriving nursery in Denison, Texas, was recognized as the leading authority on native American grapes. So France sent an emissary, M. Pierre Viala to Denison, to work with Munson in about 1886. Viala returned to France the following year, and through him, the entire French wine industry began anew, by grafting the various well-tested French *vinifera* fruit woods onto resistant American *Vitis labrusca* root stock -- primarily mustang grape plants from Central Texas! And Thomas V. Munson was awarded the Chevalier du Merite Agricole of the Legion of Honor on January 1, 1889, for his significant part in saving the vineyards, and wineries, of France.

GEOLOGY AND WINE

Peter R. Rose

Bedrock Type and Wine Quality

Geologists try to relate almost everything to geology. Given the great variety of grape and wine varieties, it is an almost irresistible temptation to look for connections between bedrock types and wine types. Moreover, the coveted "Appellations d'Origine controlee" boundaries of France are fixed according to combined criteria which are geological, topographical, and pedological. Surely there must be firm relationship between bedrock geology and wine types or wine quality!

Alas, an objective review of the recent literature on the subject indicates it is not so, at least not directly so. Authorities such as Seguin (1986) list the following factors that impact wine constitution and quality:

1. Climatic conditions;
2. Heat/light aspects of microclimate relative to the training system;
3. The cultivar and rootstock;
4. Annual Yield of the vines;
5. Topography;
6. Mineral nutrition (especially nitrogen) of the vine;
7. Water supply to the vine;
8. Soil characteristics, primarily soil structure.

In Europe, "Grand Cru" vineyards and wines are located on all the main rock types. According to Seguin (1986, p. 862) "not one single soil constituent or element may be said to be an absolutely decisive character in wine quality". Other authorities agree. Pomerol writes (1989, p. 246), "in general, the nature of the underlying geology does not seem to have a decisive influence on the quality of wines in the Bordeaux region". Thus vineyards producing the best red wines may grow their vines on soils developed upon bedrock lithologies as diverse as Quaternary alluvial gravel and sand, echinoid limestone, or even local very argillaceous outcrops. Conversely, the same source rock may give rise to wines which vary markedly in quality between wine-growing regions.

Schuster (1989) has the following to say:

> Of course soil is important. However, its significance is much more for growers as a basis for successful vine growing than it is for drinkers in terms of recognizing and enjoying what is in the glass. The grower needs to know what vines are best suited to the soil he has in the region where he lives; but from one wine-growing country to another, there is little correlation between individual soil and quality of wine or its particular characteristics.
>
> Received wisdom is that sand produces light, quickly maturing wines; chalk yields supple wines with an exalted varietal character; gravel provides finesse; clay, a heavier firmer style. This is true in only the most general way. And whereas

I can dip my nose into a glass and take pleasure in recognizing a Cabernet style and flavor, be it from Bordeaux, Bulgaria or Chile (and if I know the property, there is added enjoyment to be had from associations with the place, people and occasions), I very rarely say to myself, 'that brings back memories of calcareous clay with an overlay of limestone... Mmmmmm'. I do sometimes make a more general comment about an "earthy" or "minerally" character in the wine though.

Even if you know the soil of a given vineyard, what you see on the surface is a very limited reflection of the complex underlying geology. Although the relationship between vine roots and their habitat is a crucial one, and certainly accounts in part for differences in style and quality, for all the ink expended on it, the precise link between soil quality and flavor is not easy to identify in the wine.

The *Terroir*

This brings us to the nebulous concept of "the *Terroir*", a vague French term that comprises all the natural factors that affect a particular vineyard:

soil, subsoil and host bedrock;
drainage;
slope and exposure to sun and wind;
microclimate, including temperature and rain.

The concept is important but mysterious and essentially subjective: although subtle elements of wine taste and character may be unique to certain vineyards, it does not seem to be possible to determine (or isolate) which factor of the *terroir* produces which effect. In addition, the human impact -- especially cultivation procedures, plus rootstock and cultivar origins -- as well as natural weather variations also impact wine taste, character and "personality". How can they be separated?

In most wines and vineyards, they cannot be discriminated, especially in a predictive way. We can only note a generally characteristic taste and "personality" of wine from a specific vineyard, and ascribe them -- knowingly, of course -- to the "*terroir*".

Conclusions

So can we say anything about the relationship between bedrock geology and wine? There *are indeed* some indirect patterns, some general attributes which characterize better vineyards and vintages, aspects of "*Terroirs*" which are almost universal requirements:

1. Most quality vineyards are located on sunny hill-slopes, not on valley floors; locations promoting warm days and cool nights are preferred.
2. Optimum soils are well structured and moderately well drained, but they do have the capacity to retain water for significant periods of time.
3. Preferred soils are not too fertile, or deep, and they commonly have an appreciable lime content (this is often enhanced by chemical additives).
4. Certain cultivars apparently prefer certain parent materials *in some districts*, but in other districts, these patterns do not hold. Seguin (1986, p. 863) points out that the Chardonnay cultivar has an affinity for marly soils, and in Beaujolais, Gamay fruitwood grown on crystalline and metamorphic bedrock produces better wines than on marly limestone.
5. It is important to have a consistent but not excessive supply of water to the roots, especially during the first part of the growing season, before the grapes begin to redden. Afterward, conditions of mild drought seem to improve wine quality, by stressing the plants somewhat. Although irrigation is used in the production of "commercial" table wines in France, the "Grand Cru" appellations forbid irrigation. However, fine wines are produced in Australia, Chile, California, and Texas under carefully monitored irrigation.
6. In *some* French wine processing districts, there are subtle differences in "personality" or "character" of wines grown on differing bedrock types. However, these vary from year to year, and they cannot be quantified. They are a part of the overall art of wine making.

Seguin (1986, p. 871) provides a good summary:

> It seems that in the Bordeaux area, the chemical properties of soils, which may be modified by chemical fertilizers or soil improvements, do not have a definite influence on the quality of harvests and wines. Certainly, the characteristics are different according to the nature of the parent material and soils (calcareous or siliceous, clayish or gravelly) but the quality of *terroirs* is perhaps better explained by considering the physical properties of soils (architecture, structure, porosity, permeability, and so on) and their consequences for root development and on regulation of water supply to the vine.

THE UNIQUE FRENCH TERM *TERROIR*

James E. Wilson

Terroir is a French wineland term for which there is no simple translation, nor is its concept easily grasped. It is the total physical environment of a vineyard -- the vine, soil, subsoil, siting, drainage, and microclimate. The natural scientist would call it an ecosystem, but *terroir* has an additional dimension. There is a human element about *terroir* -- an aura of history, the joys, the heartbreaks, the sweat, the frustrations -- attributes without measure.

The use of *terroir* is not yet commonplace in American wine vocabulary, but it is beginning to appear more frequently in English-language writings. The name slips easily into (or through) the reading vocabulary, but if one wishes to pronounce it, it is tair - wahr. Because *terroir* is such a meaningful word, I shall relate how others define the concept.

In his Making Sense of Burgundy, Matt Kramer (1989) makes an eloquent effort to explain the notion of *terroir*. To understand the wines of the Côte d´Or, Kramer maintains that one must understand the concept of *terroir*. He points out that the physical attributes are not too difficult to comprehend, but he suggests there is also what he calls a "mental aspect". His explanation of "mental aspect" is that wine growers feel that each *terroir* should be allowed to be itself and produce the wine for which nature endowed it. The winemaker's "signature" (vinification style) is permissible, so long as it does not substitute for *terroir*. That is, vinification should not make the wine taste significantly different than the "natural" wine. This might be interpreted as a vinous equivalent of "vive la différence".

Hugh Johnson (1987) says it a little differently: "in *terroir*, the land chooses the crop that suits it best. Otherwise, why did not all French winegrowers settle for the same grape, the same techniques, the same idea of what a good wine should be?" A sense of place, an awareness of *terroir*, is the key to understanding the wines of France. Johnson suggests that knowing side streets, lanes, and history intensifies the sense of place. (Does not the geology of a vineyard give it a special identity?)

Gerard Séguine (1986), the Bordeaux enologist, laments that there are no in-depth studies of the ecosystem of *terroir*, and suggests it is because of the many factors involved.

Daniel Querre (1971), a grower in Saint-Emilion and onetime General Attorney for the Jurade de Saint-Emilion, questions any attempt to explain a particular *terroir* where only its obvious physical conditions are described. He points out that the vines find something "precious -- almost sacred" in their deep rooting. He compares the deep rooting of vines to that of the incense tree in the arid limestone country of Somaliland. He admits that many might shrug their shoulders at this "something", but he asks how else can we explain the sensory differences between two wines that are grown under the same physical conditions. Without the mystery of the "unknown something", Querre says, "I cannot explain how, simply by smelling it, one can distinguish a ´Chevel´ from a ´Figeac´."

In a less exotic example, the British magazine, The Economist (Faith, 1983), describes how the concept of *terroir* has been used by the French to counter efforts by the European Economic Community to deal with wine simply as a "brand" (a class of goods) in international trade. The French contend that good (and great) wine can come only from the certain severely limited environments -- the *terroirs*. The *terroir* pinpoints the geographical location of a vineyard with a specific climate, soil, and exposure. In other words, a wine is not just a commodity, but a distinct product from a unique place.

Terroir may sound pedantic, strange, and certainly "foreign". Why not just use the more familiar word "vineyard" -- especially in a book directed toward the English-speaking public? (As a matter of fact, I'm afraid I am guilty in numerous instances of using *terroir* and vineyard synonymously. If I told an inquirer that I was writing a book on the geology of French *terroirs*, the reaction would most probably be a polite, but puzzled "Un-huh". If I were lucky he might ask "what is a *terroir*?" To avoid the appearance of pedantry, I use vineyard in most of my outside discussions, but I think that many times *Terroir* is the better word. I hope there will be a mutual Franco-American tolerance for my lack of consistency).

Hopefully, this will acquaint the reader with the term and its meaning so that it slips comfortably into rather than through the reader's vocabulary.

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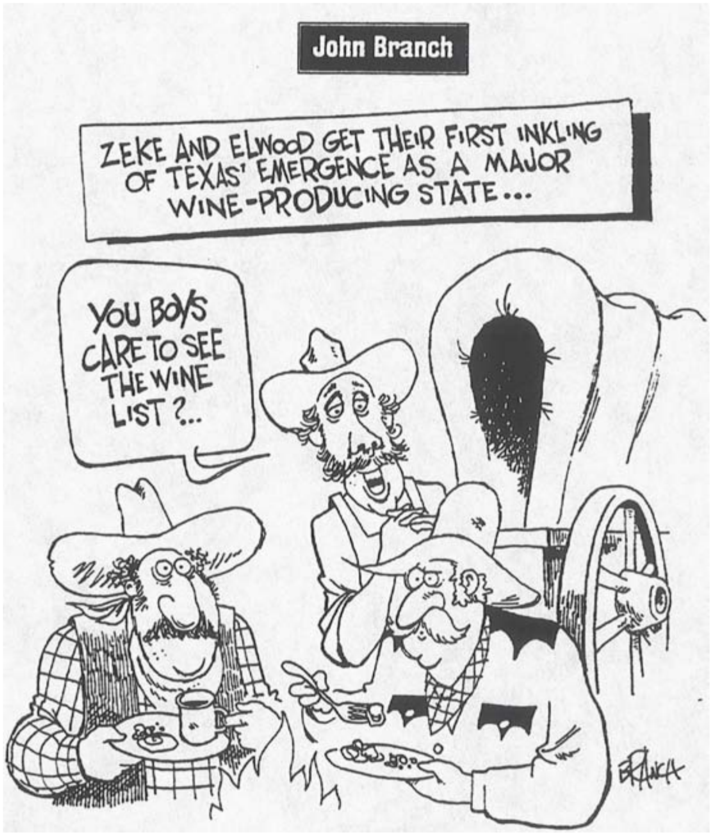
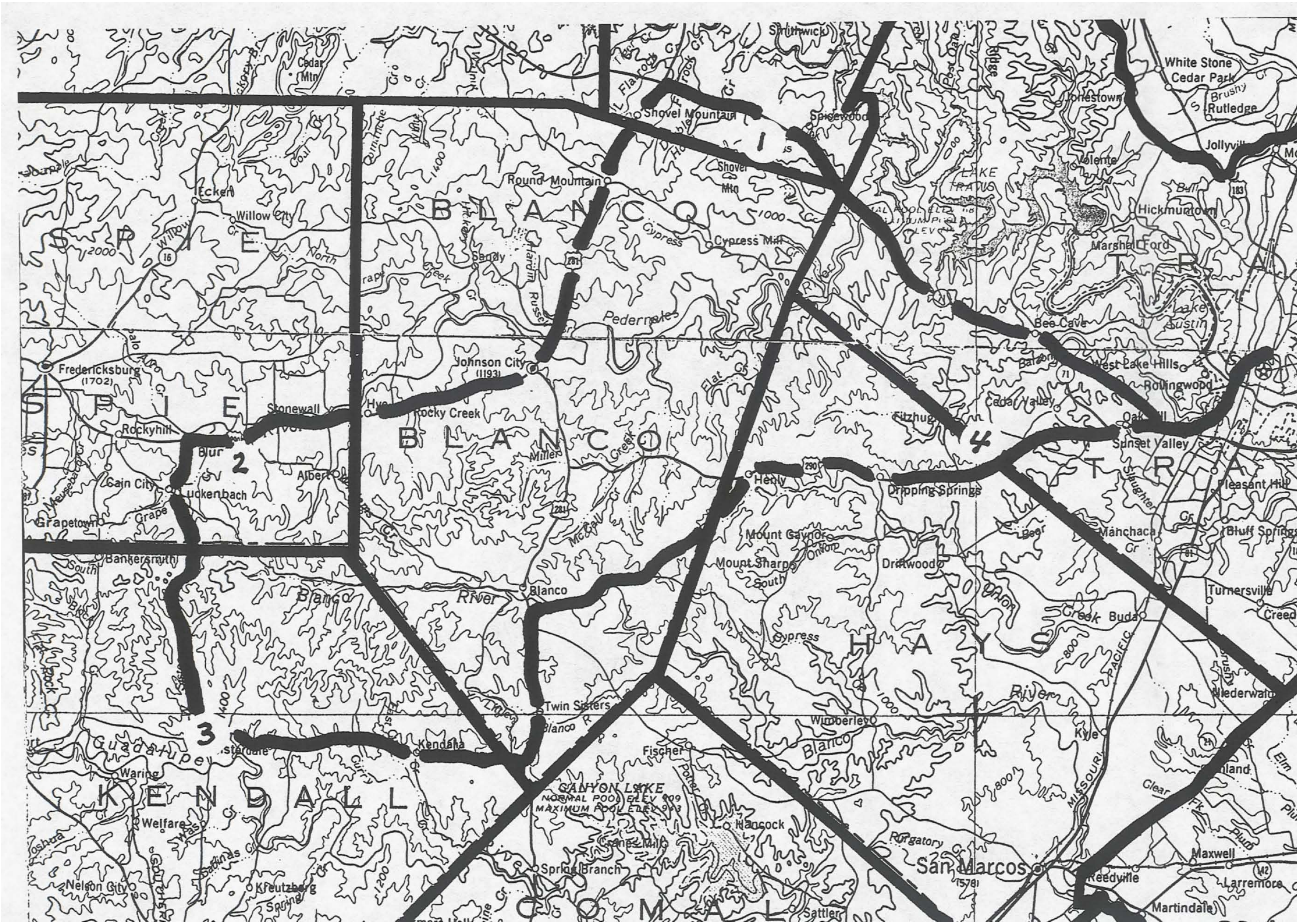


Cartoon by John Branch; Courtesy of the Wine Gazette.


BLANCO
GILLESPIE
KENDALL
COMAL
HAYS
TRAVIS
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Smithwick
Shovel Mountain
Spicewood
Shover Mtn
Round Mountain
Cypress Mill
Willow City
Ecker
Cedar Mtn
Sandy
Pedernales
Johnson City (1193)
Hye
Rocky Creek
Stonewall
Fredericksburg (1702)
Rockyhill
Blur
Albert
Cain City
Luckenbach
Grapetown
Bankersmith
Blanco
Blanco River
Twin Sisters
Kendalia
Waring
Welfare
Nelson City
Kreutzberg
Fischer
Canyon Lake
Normal Pool Elev 909
Maximum Pool Elev 943
Hancock
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Sattler
Guadalupe
Henly
Dripping Springs
Fitzhugh
Mount Gainor
Mount Sharp
Driftwood
Wimberley
Kyle
Buda
San Marcos (578)
Reedville
Martindale
Maxwell
Larremore
Niederwald
Creedmoor
Turnersville
Bluff Springs
Manchaca
Pleasant Hill
Sunset Valley
Oak Hill
Rollingwood
West Lake Hills
Cedar Valley
Bee Cave
Marshall Ford
Hickmuntown
Volente
Jonestown
Jollyville
Rutledge
Cedar Park
White Stone
Lake Travis
Lake Austin
Cypress
Onion Creek
Purgatory Cr
Clear Fork
Plum
Missouri Pacific

ROAD LOG

Tour of Central Texas Hill Country and Selected Wineries

C. M. Woodruff, Jr., Peter R. Rose, and James W. Sansom, Jr.

<u>Miles</u>

0.0 Depart Sid Richardson Hall parking lot, Manor at Red River; proceed south on Red River to 15th Street.

0.7 At 15th Street, turn right and proceed west to MoPac Expressway (Loop 1).

2.5 Turn left onto southbound access road for Loop 1.

3.0 Merge left onto Loop 1.

3.5 Cross Colorado River (Town Lake); note line of hills that compose the Balcones Escarpment on skyline to the west. The elevation at lake level is 428 ft above means sea level (msl); the hill crests in view from here rise above 900 ft msl. The trip today is a study in geographic/geologic effects--especially on wine-grape production. Key geographic attributes that will be noted in this log are our position in terms of topographic elevation and in terms of our progress in a westward direction. Both factors impose important ecologic effects.

5.6 Note apartments built on over-steepened slopes below Barton Creek Mall; pass exit for north-bound Loop 360; continue south on Loop 1.

6.2 At exit for south-bound Loop 360, note roadcut with Edwards Limestone faulted against Georgetown Formation.

6.6 Cross Barton Creek; this part of the creek lies within a City Greenbelt designed to provide protection to the Edwards aquifer and to provide public access to the creek.

7.0 Exit to South-bound Loop 1/Southwest Parkway.

7.6 Turn right on Southwest Parkway.

8.0 We are traversing the recharge zone of the Barton Springs Segment of the Edwards aquifer; note faulted Edwards in outcrop to the right.

9.3 Mount Bonnell Fault--here we cross contact from Edwards to upfaulted Glen Rose Limestone. Note subtle expression of Balcones Escarpment, as limestone is bedrock on both sides of the fault. We cross the fault line at an elevation of about 820 ft. Stratigraphic displacement here is approximately 600 ft.

Although the Balcones Fault Zone is no longer seismically active, it continues to exert profound influences on human endeavors. In detail, faulting has created a mosaic of different rock types that results in varying local ground conditions with resulting variations in engineering properties. Moreover, in addition to topographic changes across the fault line, the Balcones Escarpment marks a dividing line in terms of soils, plant and animal associations, climate and weather, surface and subsurface water regimes, and human uses of the land. As one moves west of the Escarpment, elevations generally increase and average temperatures decrease. And as one moves west, humidity decreases, as does average annual rainfall.

But more dramatic than these averages, the area along the Balcones Escarpment is a zone of climatic hazard. It is the area of highest probability of large, flood-producing storms in the conterminous United States (Hoyt and Langbein, 1955). Although of generally modest relief, the escarpment is the first substantial topographic barrier inland from the Gulf of Mexico, and there, unstable, moisture-laden Gulf air masses are forced to rise. In so doing, they cool and produce phenomenal storms. In September, 1921, more than 38 inches of rain fell in a 24 hour period near the Blackland community of Thrall in Williamson County. This compares to a usual annual rainfall rate in Austin of about 32 inches. Other storms have produced record rainfall rates for shorter periods of time. The D'Hanis Flood of 1935 (Medina County) resulted from 22 inches of rain in 2 hours and 45 minutes (Baker 1975).

Extreme precipitation events provide positive feedback to geomorphic systems: High-magnitude rains provide the means for rapid erosion, channel incision, and downstream sedimentation, all of which generally contribute to severity of future flood events, which further intensify processes of erosion, sedimentation, and the like. The Hill Country is especially prone to flash flooding, owing to the coincidence of extreme rates of rainfall, steep slopes, and a large number of small, high-gradient streams.

10.5 William Cannon Drive on left; proceed straight.

10.8 On the right is a splendid overview of the Barton Creek Watershed. There, Short Springs Branch has incised deeply, in marked contrast to the headwaters of Williamson Creek to the left. For the first time on this excursion, we rise above an elevation of 1,000 ft.

11.3 Note areas of repeated road repairs; this is a result of periodic retention of perched groundwater in the shallow subsurface. We are more than 100 ft above the permanent water table, yet this shallow groundwater undermines the roadway. Studies by Wilding and Woodruff (1996) has indicated that this problem is a result of water retention within the soil zone.

12.0 Note highly weathered outcrops of uppermost (dolomitic) member of Glen Rose Formation.

12.2 Intersection with Travis Cook Road; proceed straight. From here to State Highway 71 we are crossing preserve land composing the former tracts known as The

Uplands (on right) and Sweetwater Ranch (on left). These tracts, approximately 4,000 acres, were given to the Nature Conservancy as habitat mitigation for endangered bird species attendant to development of Barton Creek Properties.

12.9 Note road embankments on left. Attempts at revegetation of these cut slopes have failed repeatedly. Here, Glen Rose bedrock--on slopes greater than 30 percent--has been covered by "Colorado River silty loam" and seeded. This soil type is exotic to this terrain, and being incompatible with the substrate, this silty soil is highly subject to erosion and mass wasting. Even attempts at securing this soil cover by means of nylon mesh and large staple-like stays fails to hold the materials in place. Erosion and slumping continue.

14.7 Intersect Texas State Highway 71 (SH 71); turn right and proceed northwest.

16.6 Cross Barton Creek; note stream-gaging station--the "upstream" gage used by USGS in documenting runoff rates and peak discharge as well as for computing recharge rates and water budgets (Gandara and others, 1996-a). During the period 1978-1996, the annual mean discharge was 43.4 cubic ft per second (cfs). Maximum instantaneous discharge for this period of record was 14,900 cfs on 20 December 1991. Drainage area is 89.7 mi^2. This 300-fold increase of peak discharge over the mean is not extraordinary for Hill Country streams.

17.5 Village of Bee Cave--intersection with Ranch-to-Market Road (RM) 2244; continue straight. Note gently sloping ground to the right; this is an ancient high alluvial surface, which is now perched along the drainage divide between Barton Creek and Colorado River.

18.1 Intersection with RM 620; continue straight. Many Texas highways were originally Indian--or game--trails, and most were based on avenues afforded by the physical "lay of the land" (ridgelines, divides, major stream valleys, and the like). Texas Highway 71 is an exception. There was no highway through this part of Central Texas owing to the deep dissection of the Pedernales River and of tributaries to the Pedernales and the Colorado. Texas 71 was built only after World War II and connected various segments of old county roads.

19.3 Intersection of RM 3238 on left; this road leads to Hamilton Pool, Hammett's Crossing of the Pedernales, and eventually to Round Mountain. Continue on SH 71.

19.8 Note characteristic Glen Rose landscape with second-growth junipers ("cedars") and good grass cover. Contrast this scene with the area ahead on the left.

21.0 "Goatscape" on left indicates severe overgrazing; well-developed browse line on oak trees mark maximum reach of goats and deer.

The occurrence of juniper in the Hill Country is a hotly debated topic today, because it involves issues of endangered-species habitat and landowners' rights. But how widespread was juniper before European settlement? And in what ways have land-use practices affected its distribution? Ashe juniper is a native Central Texas tree, but before the 19th Century its geographic extent probably was held in check by periodic range fires that destroyed many junipers while maintaining a savanna--open grasslands with clumps of live oak overstory. During the times of early Anglo settlement, the land was overstocked and overgrazed. Much soil was lost to erosion. And owing to fire suppression, junipers rapidly spread into areas of former savanna. We now recognize wildfires as having general ecological benefit. But as usual, science lags behind society's need for answers.

Excellent non-technical narratives on historical land use in Central Texas (and matters relating to junipers) are provided by Robert Caro in the first volume of his biography of Lyndon Johnson The Path to Power (1983) and John Graves in Hard Scrabble (1974).

21.5 We are crossing the 98th Meridian, which, according to Walter Prescott Webb, in The Great Plains, denoted the beginning of the American West. Webb delineated an "institutional fault" along this line, across which basic changes occur in social, political, and economic institutions. This "institutional fault" is a result of increasing aridity, and the 98th Meridian roughly coincides with the 30-inch rainfall line. As one traverses from here west across Texas, rainfall declines on an average of roughly one inch for every 10 miles.

21.6 We are crossing the drainage divide between Barton Creek (to left) and streams draining to Lake Travis (to right). As with the Onion Creek basin, the Barton Creek watershed occupies an elevated upland, whereas deep dissection occurs in adjacent areas by streams draining to the Pedernales River, directly to Colorado River, and (from the edge of the Onion Creek basin) to Blanco River.

23.1 Note Shingle Hills on left; this is classic Hill Country terrain with stair-steps sculpted into the alternating beds of hard and soft limestone and dolomite composing the Glen Rose Formation. The tops of the hills are locally capped with Edwards limestone; the tree-covered fringes of these hill tops are underlain by the Walnut Formation.

24.6 Cross Bee Creek (one of at least three creeks of that name in Travis County).

26.8 Note Lake Travis vista on right.

27.5 From this high vantage point (approximately 1,080 ft above msl), we have a grand vista of the Hill Country including fault-bound Paleozoic "mountains" of the Llano country on the horizon straight ahead. From here, we descend into the valley of the Pedernales River.

28.9 Cross contact between Glen Rose Limestone and Hensel Sand; this contact is gradational and thus is often difficult to map.

29.5 Cross Pedernales River (here part of Lake Travis impoundment); bluffs above the river are Cow Creek Limestone, which underlies the Hensel Sand. The Hammett Shale occupies lower slopes along the lake, but it is typically covered by blocks of Cow Creek Limestone. The name of the river is from the Spanish word, pedernal, meaning flint. Examination of the bed load of this river shows this to be an appropriate name.

From here to Spicewood, we will traverse back and forth between Hensel Sand and Glen Rose Limestone. Note distinctive vegetation typical of each unit: The Hensel supports post oak and mesquite trees, as well as live oaks, cedar elms, and the ubiquitous junipers; the Glen Rose typically supports a live oak/juniper overstory with local Spanish oaks and cedar elms.

34.2 Leave Travis County; enter Burnet County. Organized in 1854, Burnet County was named for David G. Burnet, provisional president of the Republic of Texas during the Texas Revolution.

36.8 Intersection with Spur 191; continue straight. Downtown Spicewood is about one mile to the right.

37.0 As we approach Sycamore Creek, we descend from Hensel Sand onto Cow Creek Limestone and Hammett Shale, but the contacts are obscured by widespread alluvial cover.

37.3 Cross Sycamore Creek.

37.4 Turn left onto Burnet County Road #408.

37.6 Cross Sycamore Creek again.

37.8 Ascend back onto Hensel Sand.

38.1 Turn right onto Burnet County Road #407. Proceed for about 1.5 miles to Spicewood Vineyards.

39.5 Turn Left into Vineyard.

STOP 1--SPICEWOOD VINEYARDS
(<u>see</u> Geologic Setting)

Depart Spicewood Vineyards and return to SH 71.

41.6 Turn left on SH 71; proceed west and cross Cypress Creek. For approximately the next 1.8 miles, we are crossing flat terrain underlain by Sycamore Sand, the basal Cretaceous rock unit in Central Texas.

42.4 Here we cross from Cretaceous rocks onto the Marble Falls Limestone, of Pennsylvanian age. We have now crossed the great Paleozoic/Mesozoic erosional unconformity, termed the Wichita Paleoplain by R.T. Hill (Hill, 1901, p. 363). Over approximately the next 25 miles, we will cross back and forth across this unconformity many times. With these exposures of Paleozoic rocks, we are skirting the edge of the Llano Uplift.

Within the next 0.2 mile, we move down section and cross the contact with Barnett Shale of Mississippian age and a tiny outcrop of Doublehorn Shale of Devonian/Mississippian age. Paleozoic stratigraphy is based on Bureau of Economic Geology maps, including both 7.5-minute Quadrangles (scale of 1:24,000) and Geologic Atlas Sheets (scale of 1:250,000).

The Llano Uplift has a long history of geologic investigations, and it has held allure in the public mind as possessing possible mineral wealth (Dobie, 1930; Evans, 1975). The name, Central Mineral Region, is often applied to the area, but apart from bulk-rock commodities--stone, feldspar, industrial sand, and vermiculite, for example--spectacular mineral riches (i.e. production of precious metals) have proved elusive. Geologic surveys of the region have been conducted by notables such as C.D. Walcott, Theodore Comstock, E.O. Ulrich, Bailey Willis, and Sidney Paige. However, more than any other geologist, Virgil E. Barnes (1903-1998) is identified with the Llano Uplift. During a career at the Bureau of Economic Geology that spanned more than 60 years, he unraveled many of the enigmatic geologic puzzles of this region and published a great number of reports and maps at various scales. The superb work of Barnes and his various colleagues has resulted in a rare depth of understanding and set a high standard of quality. Maps used in the compilation of this log include the following credits to Virgil Barnes: Barnes (1965, 1965-a, 1966, 1974, 1978, 1981, 1982, 1982-a, 1982-b).

42.6 Cross contact with Honeycut Formation of the Ellenburger Group (Ordovician); we will continue on this hard, carbonate-rock unit for about the next 2 miles.

Interest in outcropping Ellenburger carbonates of the Llano Uplift increased dramatically after oil was discovered in the Ellenburger at Big Lake Field in 1928. Before that, all Permian Basin oil was thought to occur in the "Big Lime," a field term applied to various massive Permian dolomite units (San Andres, Clear Fork, Wolfcamp, etc.) in different parts of West Texas. The same company, Texon Oil and Land Company, that had first found oil in the "Big Lime" at Big Lake in 1923 (Santa Rita No. 1) subsequently drilled what was in 1928 the deepest well in the world (8.525 ft). They found a new deep pay in the Lower Ordovician Ellenburger "Lime." This set off a new wave of deeper exploration, focused on the Central Basin Platform, which proved to be spectacularly successful. Indeed, a substantial part of the University Lands mineral wealth has come from the Ellenburger, second only to the San Andres as a prolific West Texas reservoir. The landmark University of Texas Publication No. 4621 on the Ellenburger Group by Preston Cloud and Virgil Barnes (1948) was a response to intense industry interest in the Ellenburger.

44.7 After crossing this small, dry creek, we cross fault-bound exposures of Barnett Shale and Doublehorn Shale, and then descend back onto Ellenburger.

45.0 Again, cross down-faulted section of Barnett and Doublehorn and once again traverse Ellenburger until crossing Double Horn Creek.

45.2 Near Double Horn Creek, we cross a fault that has juxtaposed Marble Falls Limestone against Ellenburger.

46.0 Cross fault onto upfaulted Ellenburger.

47.1 For the next mile we cross several outliers of Hensel Sand, which are recognized because their sandy soils support post oak trees. Outside these outliers, bedrock is Ellenburger.

50.4 Cross overpass intersection with U.S. 281. Turn onto south-bound exit; proceed toward Johnson City. We remain on Ellenburger for about the next half-mile, then we again cross outliers of Cretaceous sandstone units for about 0.7 miles.

53.2 Leave Burnet County; enter Blanco County. Organized in 1858, Blanco County takes its name from the Blanco River, which in turn, was named for the white limestone outcrops along its course.

54.4 Ascend section from Ellenburger onto Cretaceous Hensel Sand.

54.6 Note peach trees growing on left; the famed Central Texas peach orchards thrive on the Hensel Sand.

55.0 Cross contact with Glen Rose Formation.

55.7 Descend back onto the Hensel Sand.

56.7 As we cross North Cypress Creek (not the same as that crossed in the Spicewood vicinity, this one a tributary of Pedernales River), we again cross the basal Cretaceous contact, this time onto members of the Wilberns Formation, of Cambrian Age.

56.9 Enter the village of Round Mountain (elevation 1,280 ft); intersect RM 962 on right and continue straight. Round Mountain is named for the isolated "peak" (elevation 1,595 ft) approximately 2 miles to the northwest. It is capped with Comanche Peak Limestone; here the Glen Rose Formation is about 270 ft thick.

57.1 Eastbound RM 962 on left; this road leads to Cypress Mill, Hammett's Crossing of the Pedernales and Hamilton Pool.

57.6 Note outcrops of Wilberns Formation (San Saba Member) on left. Ahead, we cross onto Point Peak Shale member of the Wilberns.

58.0 Cross Stribling Creek. Here we have crossed a fault that displaces the San Saba Limestone down against the Point Peak Shale and the Morgan Creek Limestone.

58.6 After crossing this unnamed creek, we once again cross the Paleozoic/Mesozoic boundary and traverse the Hensel Sand.

59.7 Cross Cypress Creek, which has eroded through the Hensel Sand to expose Cambrian limestones in the creek bed.

60.8 Ascend onto Glen Rose Limestone. Here, mapping by Barnes (1978) shows the <u>Corbula</u> bed to lie at the basal contact of the Glen Rose. Throughout most of

Central Texas, the Corbula bed denotes the boundary between the lower and upper members of the Glen Rose. The occurrence of the Corbula bed near the base of the formation is a dramatic illustration of how the ancient environment of deposition of the Hensel Sand displaces the carbonate environments of the Glen Rose progressively higher in the section as the source areas in the Llano Uplift are approached.

63.7 Cross Cottonwood Creek; Cambrian rocks in creekbed.

65.9 Junction with RM 1323, road to Sandy; continue on U.S. Highway 281. Here, we are near the contact between Hensel Sand and Ellenburger.

67.0 Straight ahead, on horizon, are hills capped by Edwards Limestone. This area comprises the eastern limit of the true Edwards Plateau uplands, as defined by continuous Edwards Limestone (Woodruff, 1997).

67.5 Cross the Pedernales River, where a stream-gaging station monitors a watershed of 901 mi^2 (Gandara and others, 1997). During the 57-years of record (1939-1996), the annual mean discharge was 189 cfs. Maximum instantaneous discharge was 441,000 cfs recorded 11 September 1952. This extraordinary discharge event is more than 2,000 times the annual mean rate. This flood was responsible for large cypress trees being truncated about 12 to 15 ft above the low-water crossing of the Pedernales at Hammett Crossing. This truncation presumably was caused by the saltation of boulders carried in this flood.

In comparison, this peak flow rate is more than three times the instantaneous peak discharge of the Brazos River at Waco (period of record--1898-1996). There, the Brazos has a drainage area approximately 20 times larger than the Pedernales! The annual mean discharge of that Brazos station is 2,334 cfs, a value 12 times that of the Pedernales (Gandara and others, 1997-b). These data nicely illustrate the "flashy" behavior of Hill Country streams.

67.7 Bedrock at the river crossing is Tanyard Formation of the Ellenburger Group. Here, we again cross the basal Cretaceous contact. Except for local, isolated inliers of Paleozoic rocks, the remainder of the day will traverse Cretaceous bedrock and Quaternary surface deposits.

68.4 Corporate limits of Johnson City (elevation 1,197 ft); this is the seat of Blanco County and the boyhood home of Lyndon B. Johnson. The town is named for forebears of LBJ.

68.9 Intersection with U.S. Highway 290; turn right.

69.3 LBJ boyhood home is down street to the left.

69.5 Blanco County Courthouse is one block to the right. Most of the drive between here and Hye is on Glen Rose Limestone. Locally, along creek bottoms, we descend onto Hensel Sand. Local outcrops of Paleozoic strata are noted in the log.

70.8 Cross Flat Creek.

73.9 Cross Towhead Creek

74.9 We are traveling west on Glen Rose Limestone. From this hill look to the right; there we see the edge of the Llano Uplift with fault-bound Paleozoic strata forming "mountains," Smith Mountains, Andy Moore Mountain, Dungeon Mountain, Bee Rock Mountain, Skillet Knob, Indian Peak. Most of the Precambrian rocks, especially the granites and schists, typically form lower relief terrain. Hence, the Llano Uplift is a structural dome but a topographic basin that is flanked by the high-standing limestone terrain.

75.0 As we descend from the Glen Rose onto the Hensel, note the peach orchards, which we will become more and more common as we approach Fredericksburg.

76.1 Cross Rocky Creek; Cambrian Wilberns Formation is exposed in the creek.

76.9 Ascend back onto Glen Rose Limestone.

77.4 Road to Sandy (RM 1320) on right.

77.8 As we crest this hill we get another view to the right of "mountains" approximately 17 miles to the north.

78.9 Enter Hye (elevation 1,453); note decorated general store and post office on left. Here, we descend from Glen Rose back onto Hensel Sand as we cross Langhein Branch.

79.3 Intersect RM 1 on right; this scenic road along the Pedernales River leads to the LBJ Ranch.

79.6 Cross Williamson Creek; note wide alluvial valley.

80.1 Leave Blanco County; enter Gillespie County. Organized in 1848, Gillespie County was named for Texas Ranger Captain R.A. Gillespie; the county includes the birthplace of President Lyndon B. Johnson, and Fleet Admiral Chester W. Nimitz.

81.4 Intersection with Lower Albert Road; note old American Church to the right; continue straight. The rest of the way along U.S. 290, were we are driving parallel to the Pedernales River, which ranges in distance from a few hundred to a few thousand ft.

82.7 Entrance to LBJ National Historic Park on right.

83.0 On right, note pioneer log houses with vernacular "dog-run" architecture.

84.2 Intersect RM 1623 on left; proceed straight through Stonewall (elevation 1,512 ft), established in 1870 and named for Confederate General, Thomas J. ("Stonewall") Jackson.

85.5 Intersect RM 1 on right; continue straight.

86.1 Upper Albert Road on left; continue straight. After crossing Threemile Creek, we cross several small inliers of Tanyard Formation (Ellenburger Group) surrounded by Hensel Sand.

87.5 Intersection with Jenschke Lane (Elgin-Behrends Road on sign); turn left.

88.8 Past radio-navigation beacon on right, and past vineyard, turn right onto Becker property.

89.3 Turn right to winery.

STOP 2--BECKER VINEYARDS
(see Geologic Setting)

89.4 Turn around and retrace route back to U.S. 290.

91.2 As we approach the highway, note again the fault-bound mountains to the north. Turn left and proceed west on U.S. 290.

92.4 On the left is Grape Creek winery. The vineyards here have been ravaged by Pierce's Disease, a bacterial infection carried by insects. Infected vines have to be destroyed.

92.7 Cross South Grape Creek.

Vernacular names often provide clues about local environmental conditions. It seems to be a coincidence that two wineries of the Central Texas appellation are sited along a creek of this name. As noted by Johnson (1994), "Texas has a special place in the history of the vine, if not of wine. It is...the region with more native grape species than any other on earth. Of 36 species of the genus Vitis scattered around the world no fewer than 15 are Texan natives..."

93.4 Turn left onto paved road; proceed south.

95.9 At bend in road we are driving parallel to South Grape Creek.

96.4 Note cut-stone farm house on right.

97.2 On the right is Luckenbach School, first established in 1855 and initially housed in a log building, this stone structure was built in 1905. School consolidated with Fredericksburg in 1964, the building now serves as a community center and polling place.

97.5 Intersection with FM 1376; turn left, then immediately, before crossing Grape

Creek, turn right again and proceed into Luckenbach.

97.7 Luckenbach Store (elevation 1,561 ft)--Lunch Stop.

This community was established in the 1850's by German settlers, but it remained obscure until purchased in the 1970's by the late "Hondo" Crouch. When asked why he bought it, he was reported to have said, "I always wanted to own a city, and Clint wouldn't sell me Dallas." The site was home to several Luckenbach "World Fairs" organized by Crouch, and a song by Jerry Jeff Walker and the Lost Gonzo Band made the name of this hamlet known virtually worldwide.

Luckenbach Store serves as a beer tavern, traditional rural dance hall, and a sometimes-used blacksmith shop. As noted by a Texas Highway Department travel guide, the ambiance at Luckenbach "is like Brigadoon; you're almost afraid to go back because it might not be there again."

After lunch, turn around and return to FM 1376.

97.9 At FM 1376 turn right, and cross South Grape Creek.

98.4 Here we cross the Hensel/Glen Rose contact one final time. The remainder of the trip will traverse Cretaceous carbonate rock units and Quaternary surface deposits.

99.6 Intersection with RM 1898; continue south on FM 1376.

100.1 Flat-topped upland straight ahead is a narrow remnant of the Edwards Plateau, which stretches along major drainage divides as finger-like extensions from its vast undissected reaches in west-central Texas.

101.6 Leave Gillespie County; enter Kendall County. Kendall County was organized in 1862 and was named for pioneer stockman and journalist, George W. Kendall.

102.2 Note mass wasting on right.

104.1 We have crossed the upper contact of the Glen Rose Limestone and are now driving on Edwards terrain (lower part of the Fort Terrett Formation [Rose, 1972]) as we rise to the crest of the drainage divide separating the Pedernales watershed from the drainage basin of Guadalupe River. In the larger context of state-wide drainage, this divide separates two of the major coastward-flowing river systems of Texas--the Colorado to the north, the Guadalupe to the south.

104.6 As we cross the divide at an elevation of 1,950 ft, we see the spectacular southern edge of the Edwards Plateau. Here, tributaries to Guadalupe River have dissected the landscape, creating relief of 720 ft from divide to the main stream, over a straight-line distance of 10.3 miles (straight-line gradient of approximately 70 ft per mile). This contrasts to a gradient of about 60 ft per mile to the Pedernales River, which flows at an approximate elevation of 1,470 near Blumenthal. The deeper dissection in the Guadalupe watershed is probably a result of the greater geomorphic effects of Balcones faulting in the Guadalupe watershed compared to the Colorado basin. As discussed by Woodruff and Abbott (1979, 1986) major streams crossing the pre-Balcones Edwards Plateau probably trended west-to-east. After faulting, and with the abrupt change in relief across the newly formed escarpment, regional trunk streams trended obliquely to the fault line and were subject to capture by smaller, high-gradient streams cutting normal to the escarpment. Such processes affected Guadalupe and Blanco Rivers as well as Medina River and Cibolo Creek; they did not affect the Colorado and its tributaries, nor did they affect major streams of the Nueces watershed. Today, tributaries to the Colorado still maintain the ancient west-to-east courses, and plateau uplands within watersheds draining to the Colorado maintain the pre-faulting trends of water courses. These areas also exhibit less dissection.

105.3 Approximate location of basal Edwards contact. As descend into the Guadalupe River valley, we again cross the Glen Rose Limestone, note good expression of stair-step hills.

107.4 Exotic game ranch to right.

107.6 Cross Wenzel Creek; we are driving parallel to West Sister Creek.

108.2 On left, note slope failure in so-called marly unit of Glen Rose Limestone. The "marls" are not through-going friable or fissile strata; instead, they represent a near-surface weathered material, a regolith. A core deep in the hillside would show that the marls are bioturbated, commonly fossiliferous limestones that, when unweathered, are reasonably well indurated.

111.0 Note dissected Edwards Plateau remnants on skyline to the south. This high terrain comprises the headwaters of Cibolo Creek and adjacent parts of the Medina River basin between Boerne and Bandera.

112.6 Here we are crossing 30-degree North Latitude, cited by Wagner (1974) as the approximate southern limit for Mediterranean grapes, owing to limits on day length during growing season.

113.4 Descend from Glen Rose Limestone onto terrace of West Sister Creek.

114.2 Junction with RM 473; continue straight into Sisterdale (elevation 1,280 ft).

114.7 Winery in old Sisterdale Cotton Gin.

STOP 3--SISTER CREEK VINEYARDS
(see Geologic Setting)

Depart winery, proceed south on RM 1376/473.

114.9 Cross East Sister Creek.

115.1 Turn left onto east-bound RM 473; here we rise from the combined terrace complex of Sister Creek and Guadalupe River and are again traversing Glen Rose Limestone. For approximately the next 22 miles, we are crossing unspoiled Hill Country terrain--stair-step hills, rock-bottom intermittent creeks, and plateau uplands on the horizon.

121.4 Intersection with RM 474; continue straight.

124.7 Note outlier of Edwards Plateau on left.

128.8 Enter Kendalia (elevation 1,380 ft); intersect RM 3351 and continue straight.

131.7 As we descend to cross Simmons Creek, note peaks ahead on left (at 11 o'clock); these are the Twin Sisters, a pair of hills sculpted in Glen Rose Limestone. These hills have been used as landmarks since pioneer days, and as noted on the Geologic Atlas of Texas, San Antonio Sheet, they are near the site of the military airplane crash that killed Army Captain (and U.T. Professor of Geology) Robert H. Cuyler on 13 March 1944.

134.8 Leave Kendall County; enter Blanco County.

135.1 Cross sub-basin divide separating Guadalupe River drainage from that of Blanco River.

136.6 Intersect U.S. Highway 281; turn left and proceed north.

138.4 Cross Little Blanco River; enter the village of Twin Sisters. Intersection with RM 473 to the right; continue straight. Before crossing the Little Blanco, we again crossed 30-degree North Latitude.

143.2 Intersection with RM 32 to the right; proceed straight, and prepare to turn right.

143.6 Turn right on Loop 163 (Blanco bypass).

144.8 Turn right onto RM 165.

145.8 Cross Blanco River.

152.7 Intersection with RM 2325 (road to Wimberley); bear left and continue northeast on RM 165. Note high plateau-like terrain ahead. This marks the edge of the Onion Creek watershed (and the Colorado/Guadalupe divide). As noted when we crossed the Barton Creek watershed into that of the Pedernales, the Onion/Barton basins occupy high topographic surfaces. Abrupt downcutting and dissection has occurred on all sides. This phenomenon can be explained in part by the aforementioned processes of stream piracy. Woodruff (1976) postulates that Blanco River and Onion Creek were once part of an integrated watershed. But the Blanco River was diverted to the south, while Onion Creek, being beheaded, had less erosive power and thus has incised less vigorously.

154.1 Here we cross the divide at an elevation of 1,621 ft. We now leave the Guadalupe watershed and enter that of the Colorado River. Remnant caps of Edwards Limestone underlie the edges of this watershed; when the last of this Edwards cap is eroded, this high basin will be quickly integrated into the Blanco and Pedernales watersheds.

157.3 Leave Blanco County; enter Hays County. Hays County was established in 1843 and was named for famed Texas Ranger Captain, John Coffee Hays. A native Tennessean and a land surveyor by profession, Hays came to Texas in 1837 and won fame as an Indian fighter. Under his command, the Colt revolver was first used in organized frontier defense.

161.2 As we approach U.S. 290, we are crossing an alluvial plain that straddles the watershed divide between the Onion Creek and Pedernales drainage basins. The topographic map data suggests that part of the Onion Creek watershed has been beheaded by the high-gradient drainage to Pedernales River. So the diminished erosion by Onion Creek is further indicated. Much more work on Quaternary deposits and drainage evolution is needed; it is a fruitful area for study.

161.3 Turn right on U.S. 290. Topographic elevation here is 1,316 ft.

161.5 Pass through "downtown" Henly. From here to Oak Hill, U.S. 290 mainly traverses low divides separating the drainage basin of Barton Creek from the various tributary sub-basins of Onion Creek.

169.9 Intersect SH 12 in downtown Dripping Springs (elevation 1,156 ft) continue straight on U.S. 290.

175.4 Here we again cross the 98th Meridian.

177.4 Entering Cedar Valley, Nutty Brown Road on right.

177.7 Leave Hays County; enter Travis County. Travis County was created in 1840, immediately after Austin became Capital of Texas. It was named for William Barrett Travis, Commander of Texas forces at the siege of the Alamo.

178.3 Turn left onto Fitzhugh Road.

179.1 Cana Vineyards on left; enter gate and proceed to winery.

STOP 4 CANA CELLARS
(<u>see</u> Geologic Setting)

179.3 Turn around and retrace route to U.S. 290.

180.1 At U.S. 290, turn left; continue east.

183.3 Intersect RM 1826 (Camp Ben McCullough Road) on right; continue straight.

185.9 Oak Hill "Y"--intersection with SH 71; continue east on U.S. 290.

186.3 Cross Mount Bonnell Fault. Here we cross onto downfaulted Edwards and enter the recharge zone of the Edwards Aquifer. Here, U.S. 290 is under construction; follow signs back to Loop 1, and proceed north across Colorado River.

191.8 Cross Colorado River (Town Lake); exit onto Enfield Road. Note Austin skyline to the right. Austin was established by authorization of Congress of the Republic of Texas in 1839. But well into the last quarter of the 19th Century it remained a town of a few thousand inhabitants. Streets were unpaved, and most public buildings were made of logs or rough lumber. The first building "boom" occurred during the 1880s when the region began to recover from Civil War and Reconstruction, and new wealth from cotton and land and cattle began to flow into the Capital City. The University of Texas was founded in 1883; the present Capitol was built in 1888. Even into the early 1970's Austin remained a laid-back college town, but growth was on the horizon. Today, Austin is the nation's 22nd largest city, with a population of more than a half-million people, congested roads, crazy drivers, contentious politics, and an impressive skyline.

192.8 Turn right on Enfield Road, and retrace route to Sid Richardson Hall via 15th Street and Red River Street.

195.1 Enter Sid Richardson Hall Parking Lot.

END of TRIP

GEOLOGIC SETTING of SELECTED CENTRAL TEXAS VINEYARDS

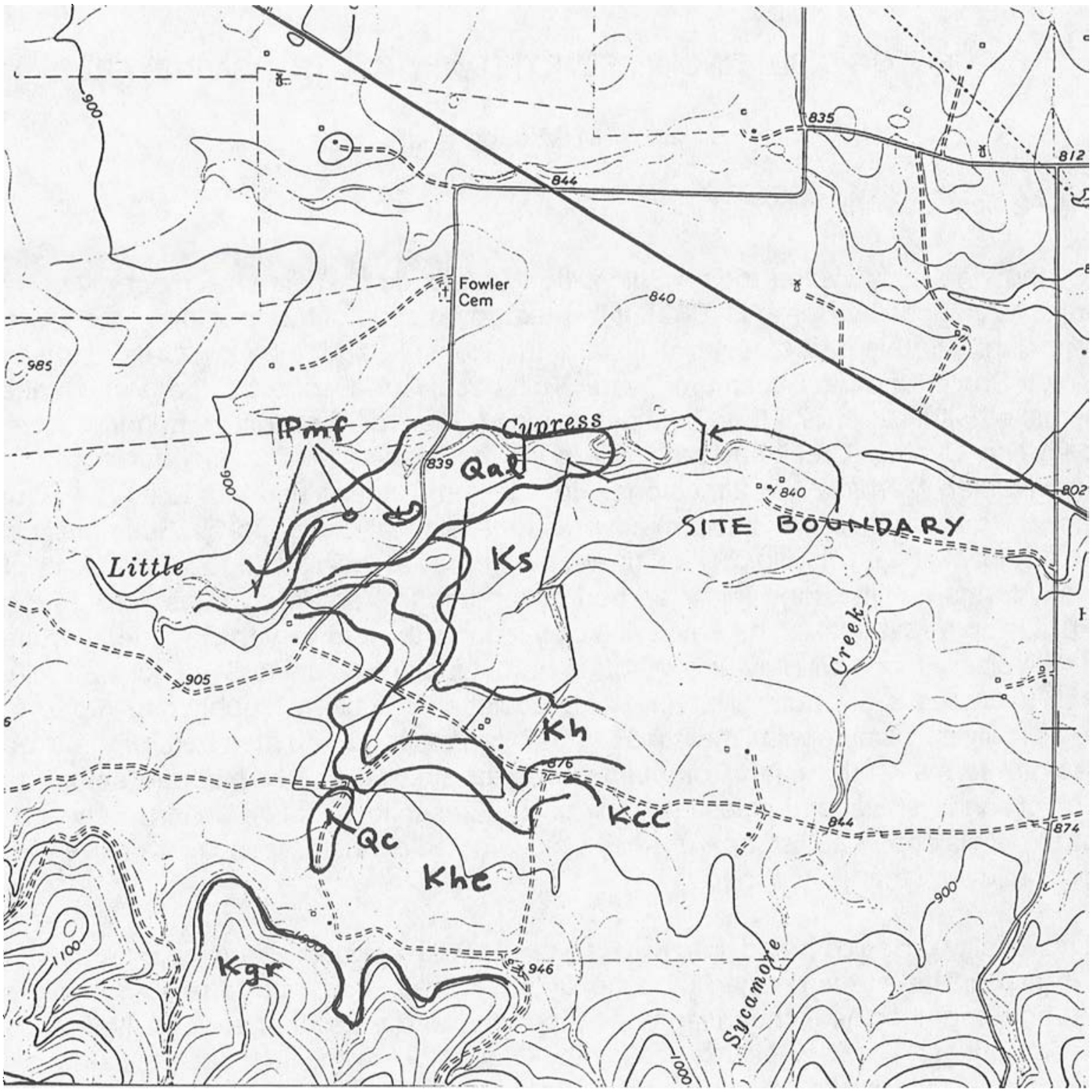
C. M. Woodruff, Jr.

Stop 1--Spicewood Vineyards

Of the vineyards visited today, Spicewood Vineyards occupies the most diverse geologic setting. As mapped by Barnes (1982), it is situated on parts of the four lower-most Cretaceous bedrock units in this part of Central Texas: the Hensel Sand; the Cow Creek Limestone; the Hammett Shale; and the Sycamore Sand. This basal Cretaceous section is much attenuated, compressed within about 75 ft of vertical section. Moreover, a scant few hundred ft west of the property line, Cypress Creek has eroded through the base of the Cretaceous section to expose Pennsylvanian Marble Falls Limestone. In addition to these bedrock units, two Quaternary surface units (alluvium and colluvium) cover extensive local areas (fig 1). Soil units include the Bolar clay loam, the Lewisville clay loam, and the Purves association (fig 2). The Bolar clay loam typically forms on limestone and marl bedrock, but in this area it overlies parts of the Hensel Sand. It is up to 3 ft thick. The Lewisville clay loam is thick to very thick, ranging from 3 to 8 ft thick. It typically forms on alluvium, although here it mainly occupies Sycamore Sand, which is, in fact, Cretaceous alluvium. Purves soil association is a stony, cobbly clay, up to about 2 ft thick, typically associated with limestones. It is often mapped with members of the Brackett soil series that forms on the Glen Rose Limestone terrain. Here, it is mapped across the entire section of sands, shale, and limestone, so this unit poses local contradictions between soil and substrate. This apparent discrepancy may be explained by the presence of a more widespread cover of alluvium than is mapped.

This locality occupies broad, gently rolling terrain, with elevations ranging from 900 ft to about 815 ft (msl). The site is drained by Little Cypress Creek and tributaries to Sycamore Creek, which flow together near the village of Spicewood and enter tailwaters of Lake Travis near Krause's Springs. These vineyards occupy foot slopes below the limestone hills that begin less than one-half mile south of the winery. There, Glen Rose Limestone is bedrock, and the landscape changes abruptly to the stair-step hills typical of much of the Hill Country. Microclimate effects are probably provided by the proximity to these hills and to Lake Travis.

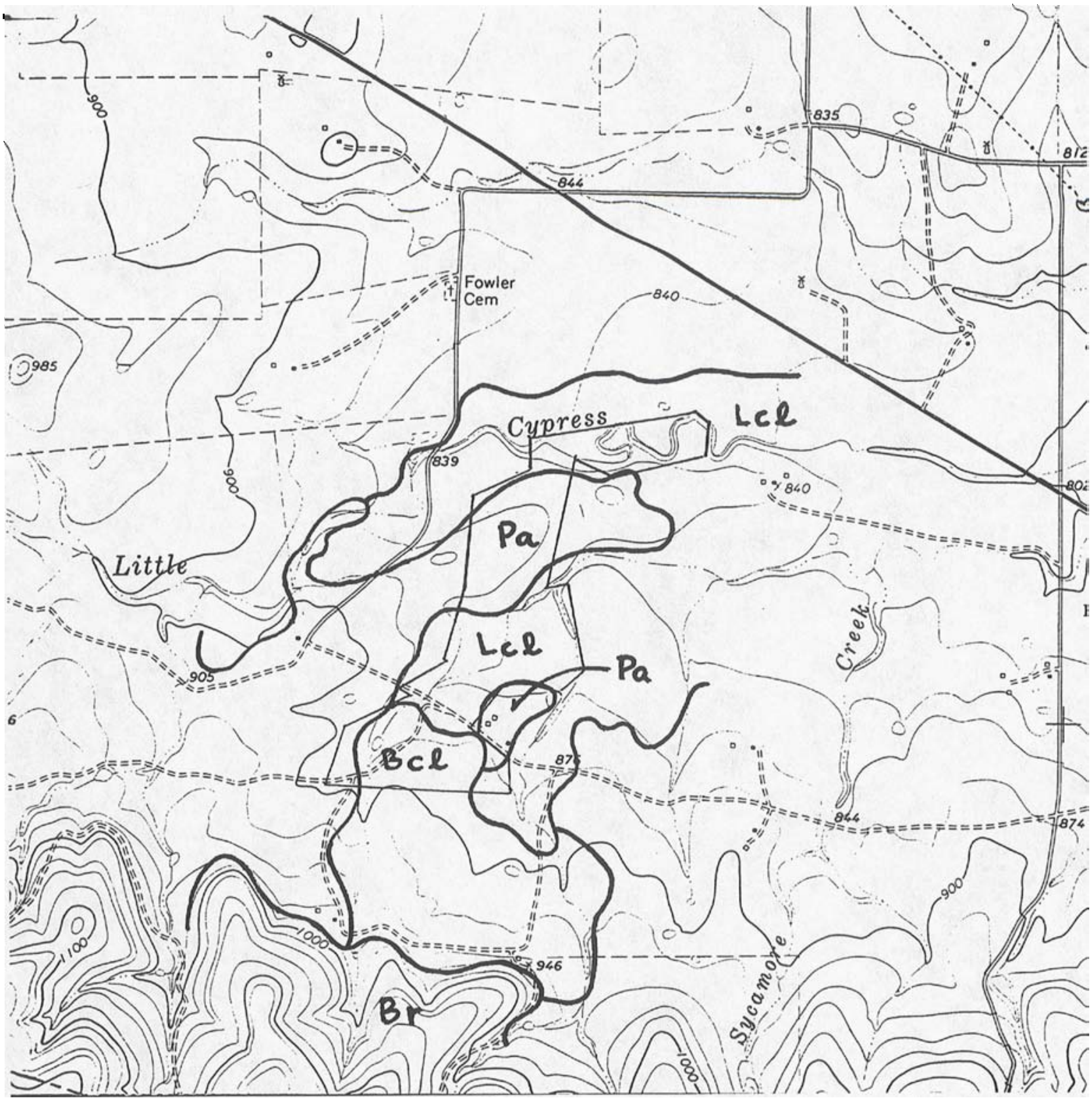
The geologic and pedologic diversity of this site offers potential for studying the intimate interplay between bedrock and soil. However, more detailed correlation between bedrock and soil is needed to resolve apparent mapping discrepancies.



Explanation:

- Quaternary surface deposits
  - Qal--Quaternary alluvium
  - Qc--colluvium
- Cretaceous bedrock units
  - Kgr--Glen Rose Limestone (off site)
  - Khe--Hensel Sand
  - Kcc--Cow Creek Limestone
  - Kh--Hammett Shale
  - Ks--Sycamore Sand
- Pennsylvanian bedrock unit
  - Pmf--Marble Falls Limestone (off site)

Figure 1. Bedrock--vicinity of Spicewood Vineyards (from Barnes, 1982--Spicewood Quadrangle); contour interval = 20 ft.



Explanation:
- Bcl--Bolar clay loam, 1 to 3 percent slopes
- Br--Brackett/Real association, hilly
- Lcl--Lewisville clay loam, 1 to 3 percent slopes
- Pa--Purves association, undulating

Figure 2. Soils--vicinity of Spicewood Vineyards (from Dittemore and Allison, 1979).

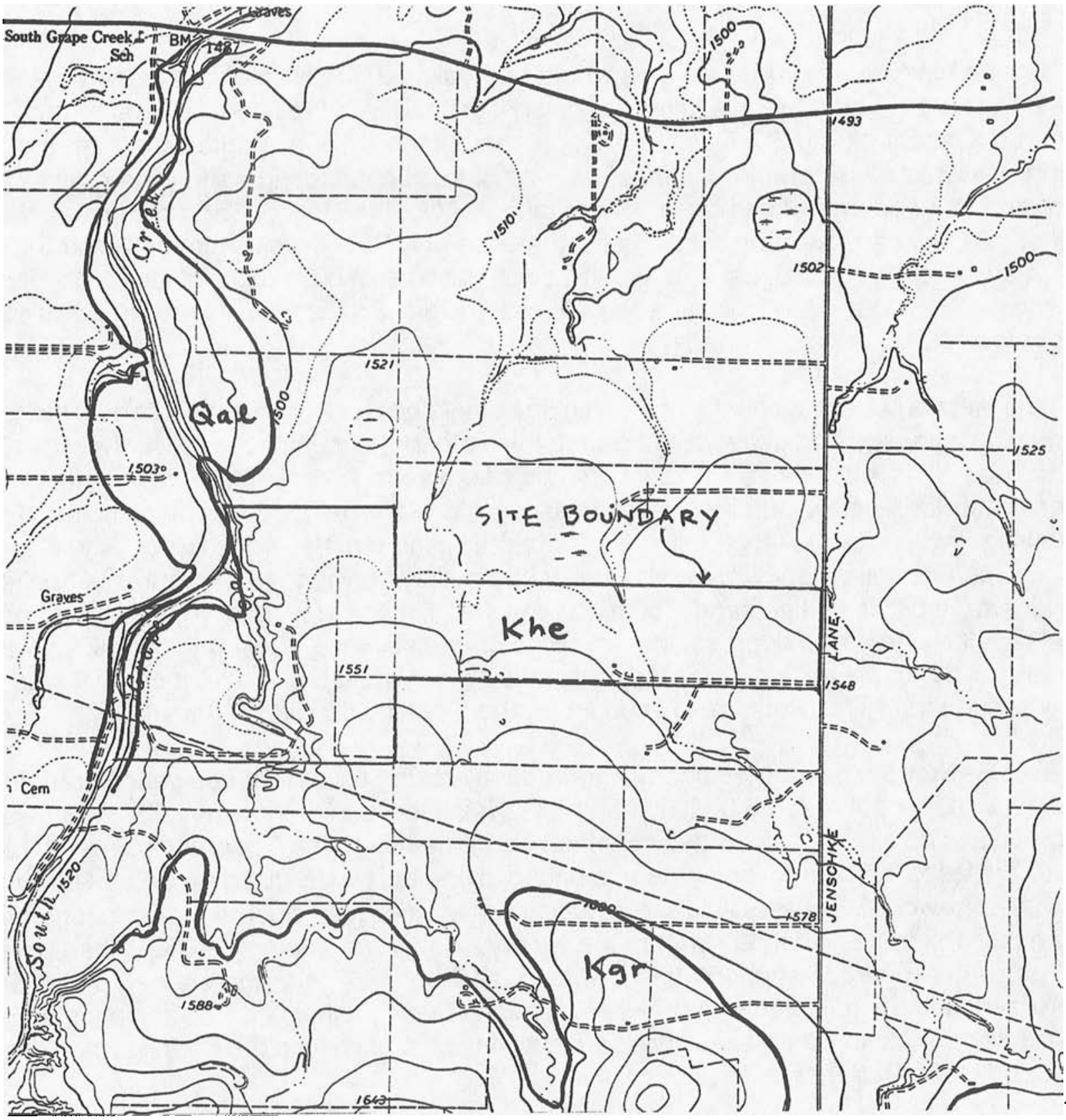
Stop 2--Becker Vineyards

Becker Vineyards is underlain by a single bedrock unit, the Hensel Sand; the western edge of the tract is blanketed by an alluvial deposit associated with the floodplain/terrace complex of South Grape Creek (fig 3). Despite the apparent simplicity of geologic substrate, the Hensel Sand presents considerable diversity in terms of local changes in sand (and gravel) texture, bedforms, and degree of carbonate cementation. Also, the Hensel Sand composes the basal unit of the Cretaceous section in this part of the state (the Cow Creek, Hammett, and Sycamore, which are mapped in the Spicewood vicinity, pinch out against older rocks of the Llano Uplift, and thus they and do not extend this far west). In fact, the pre-Cretaceous surface is exposed within two miles of the vineyard property.

The diverse substrates contained within this single bedrock unit is indicated by the fact that Becker Vineyards (of all sites visited during this field trip) occupies the most diverse setting in terms of soils (fig. 4). Twelve soil units are mapped across the tract (Allison and others, 1975). These typically deep, well-drained sandy to sandy loam soils on gentle slopes. Included are the following soil units: Altoga silty clay, Bastrop fine sandy loam, Frio silty clay loam, Guadalupe/Frio soils, Heatly loamy fine sand, Lewisville clay loam, two varieties of Luckenbach clay loam, Pedernales fine sandy loam, Purves soil, Tobosa clay, and Topia clay. In addition, local circular, undrained depressions are noted on the soil map. Owing to the alluvial origin of the Hensel Sand, the geologic map may overlook a more widespread extent of relict Quaternary alluvial surfaces. This would help account for the diversity of soils on the site.

The Becker tract occupies nearly flat, to gently rolling terrain with elevations ranging from 1,570 ft to about 1,470 ft (msl). It lies at the highest elevation of the vineyards composing this excursion. The site is drained by two unnamed tributaries to the Pedernales River, which lies about 2 miles to the north. The western boundary of the tract is delimited by South Grape Creek. As with Spicewood Vineyards, this site occupies convex foot slopes below the limestone hills that begin less than one-half mile south of the winery. And there again, the Glen Rose Limestone makes up the bedrock supporting this upland landscape. There, the stair-step hills are well expressed, and the hills afford sources of limestone alluvium that is noted in places across the tract. Microclimate effects are provided by elevation; the proximity to the north-facing Glen Rose hills, and to the Pedernales River.

The pedologic diversity of this site offers rich potential for studying the effects on specific grape quality as related to this great variety of soil conditions.



Explanation:

Quaternary surface deposits

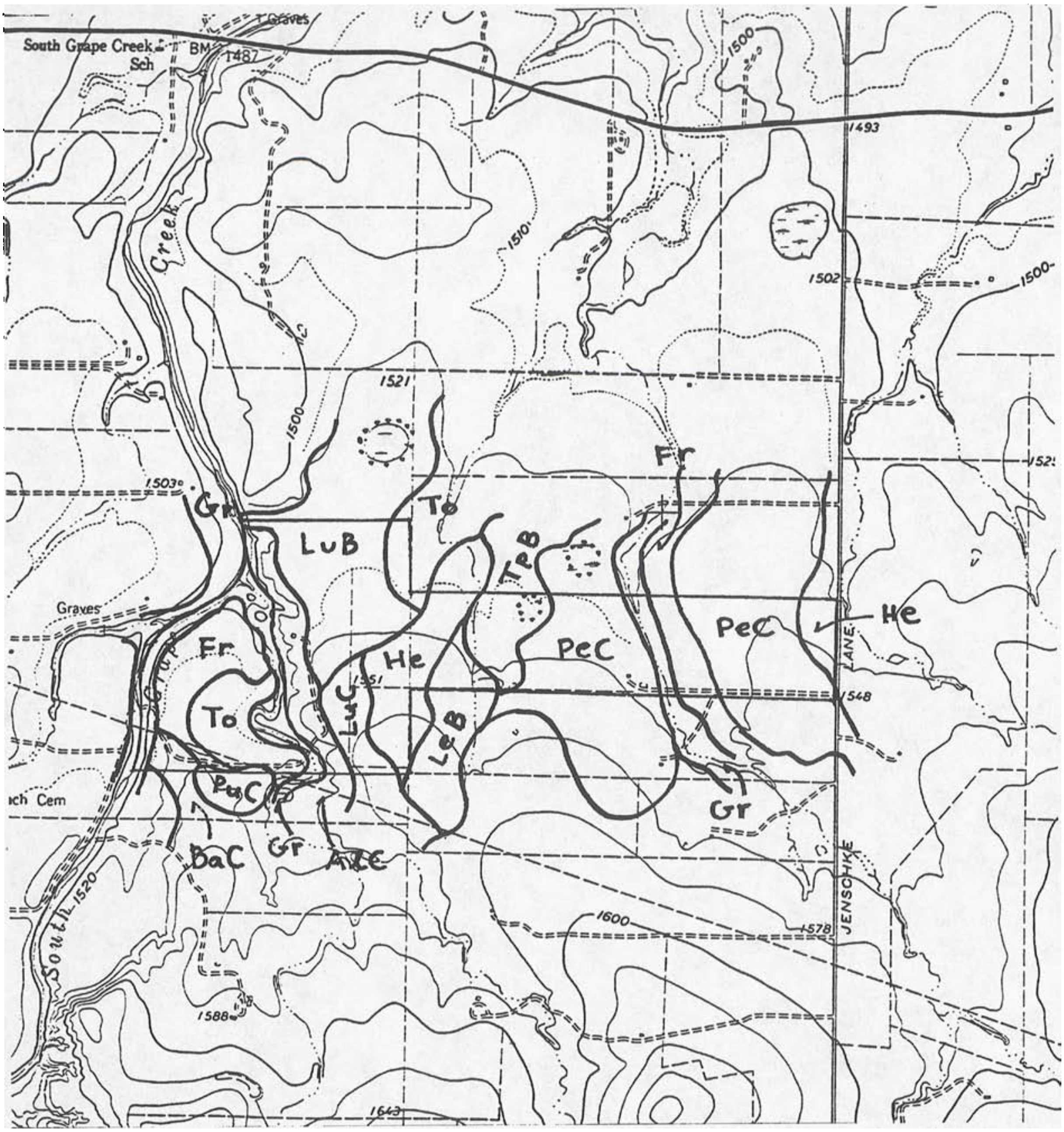
Qal--Quaternary alluvium

Cretaceous bedrock units

Kgr--Glen Rose Limestone (off site)

Khe--Hensel Sand

Figure 3. Bedrock--vicinity of Becker Vineyards (from Barnes, 1966--Stonewall Quadrangle); contour interval = 20 ft.



Explanation:

AlC--Altoga silty clay, 3 to 5 percent slopes
BaC--Bastrop fine sandy loam, 1 to 3 percent slopes
Fr--Frio silty clay loam
Gr--Guadalupe and Frio soils, channeled
He--Heatly loamy fine sand
LeB--Lewisville clay loam, 1 to 3 percent slopes
LuB--Luckenbach clay loam, 1 to 3 percent slopes
LuC--Luckenbach clay loam, 3 to 5 percent slopes
PeC--Pedernales fine sand loam, 3 to 5 percent slopes
PuC--Purves soils, undulating
To--Tobosa clay
TpB--Topia clay, 1 to 3 percent slopes

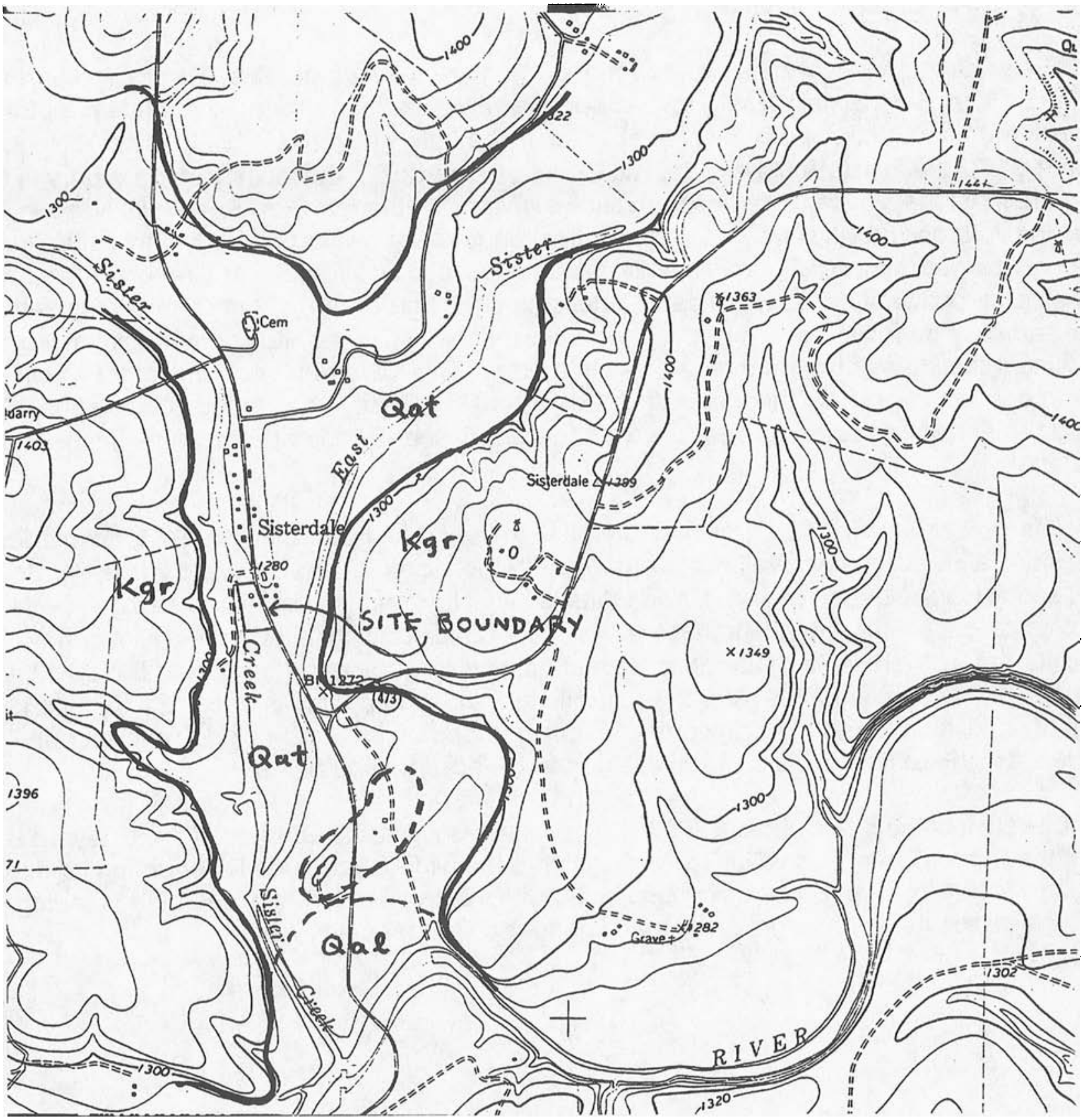
Figure 4. Soils--vicinity of Becker Vineyards (from Allison and others, 1975).

Stop 3--Sister Creek Vineyards

Sister Creek Vineyards is situated along the alluvial valley of West Sister Creek, near its juncture with East Sister Creek, and about one mile upstream from the confluence of these creeks with the Guadalupe River (fig. 5). This is the only vineyard visited today that is located within one of the incised valleys of the Hill Country. Bedrock in the vicinity of the winery is Glen Rose Limestone, which underlies the valley alluvium. Although Glen Rose hills surround this location, bedrock provides only an indirect effect on grape-growing potential at this site: that is, through the sediment eroded from the hills and redeposited by West Sister Creek. This alluvium consists of rounded fragments of coarse limestone and chert gravel within channel deposits and silt and clay deposited in overbank floodplain reaches. These alluvial materials make up a sediment thickness of more than 20 ft in this area. This valley-fill alluvium contrasts with the sediment seen a few thousand ft downstream. There, the broad Guadalupe River floodplain/terrace complex contains fewer coarse clasts and a greater percentage of fine-grained materials.

The valley alluvium of Sister Creek give rise to very rich, thick soils (fig. 6) derived from the limestone alluvial sources. Valley soils mapped in the vicinity of the vineyard consist of Boerne fine sandy loam, Nuvalde silty clay, and Oakalla silty clay loam. Boerne fine sandy loam is well drained and typically extends to depths of up to 4 ft. Its friability allows deep root penetration, and its natural fertility is moderate. Nuvalde silty clay is a deep (more than 5 ft thick), well-drained soil with high natural fertility. Oakalla silty clay loam, also is deep (5 ft thick) and is a well-drained, high-fertility soil. In contrast, soils mapped on the hills include Brackett and Doss series, which are thin and stony and are generally lacking in nutrients.

Elevation of the site is about 1,280 ft, but the main topographic attribute of the vineyard is the south-facing aspect of this valley as it opens onto the wide Guadalupe River bottomland to the south. Micro-climate effects are provided by the site's being nestled between high-standing hills and the proximity of the large, perennial, spring-fed Guadalupe River.



Explanation:

Quaternary surface deposits

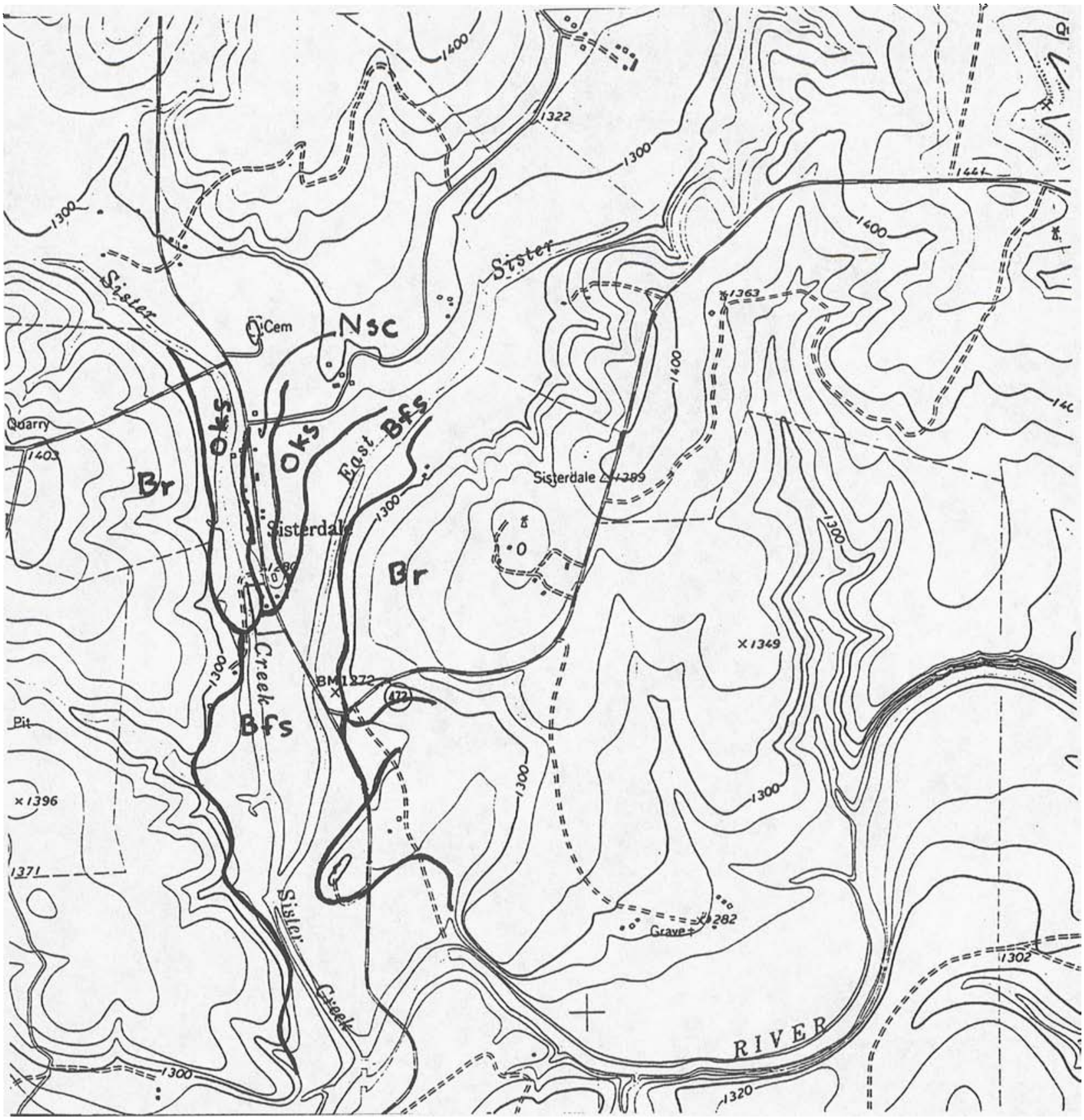
Qal--Quaternary alluvium--Guadalupe valley

Qat--Quaternary alluvium--side valley

Cretaceous bedrock units

Kgr--Glen Rose Limestone (off site)

Figure 5. Bedrock--vicinity of Sister Creek Vineyards (modified from Barnes, 1974); Topographic map--Sisterdale Quadrangle; contour interval = 20 ft.



Explanation:

Bfs--Boerne fine sandy loam

B/D--Brackett/Doss complex (uplands--off site)

Nsc--Nuvalde silty clay, 1 to 3 percent slopes

Oks--Oakalla silty clay loam

Figure 6. Soils--vicinity of Sister Creek Vineyards (from Dittemore, and Hensell, 1981).

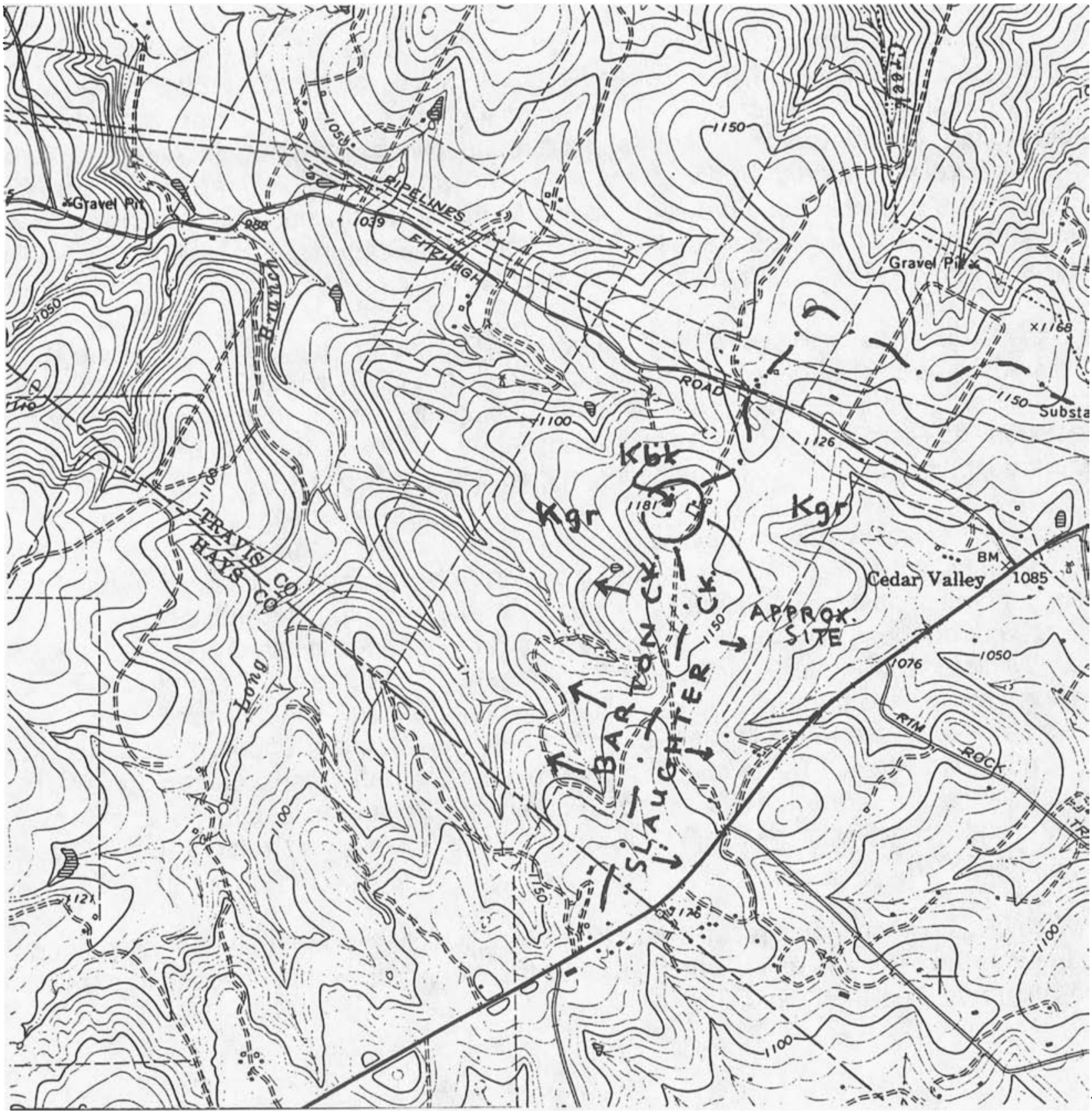
Stop 4--Cana Cellars

Of the four vineyards visited during this trip, Cana Cellars occupies a unique geologic/geographic setting. It is underlain by limestone bedrock, and although its elevation, at about 1,175 ft, is not the highest of wineries composing this excursion, it is situated on the most "upland" site--near the drainage divide separating headwaters of Slaughter Creek to the south from those draining north to Barton Creek. Growing grapes on the Cretaceous Limestones of Central Texas probably pose problems, owing to the discontinuous nature of soils. But it is notable that some of the grand sites in France's Côte d'Or (Burgundy Region) occupy limestone uplands (Johnson, 1994), and these vineyards produce some of the world's finest wines.

Cana Cellars vineyard is underlain by the Walnut Formation (Bull Creek Limestone Member) just above the contact with the Glen Rose Limestone (fig. 7). The Bull Creek Limestone unit is typically hard, and is medium to thin bedded, although it contains nodular to friable horizons. The underlying Glen Rose Limestone consists mainly of soft, friable dolomite beds that are highly weathered, producing silty soils containing myriad dolomite rhombs.

Soils in the vicinity of the vineyard consists entirely of one member of the Brackett Series, which is the typical soil unit across most of the Glen Rose uplands west of Austin (fig. 8). This soil is generally considered to be thin and stony, with a maximum thickness of only about 2 ft. Recent work on these Hill Country soils has shown them to possess a diversity not previously noted (Wilding, 1997). On the stair-step hills, the gently sloping "treads" are underlain by hard limestone strata, and there, the soils are indeed thin or absent. On the more steeply sloping "risers", the soils are much thicker, although they are still stony and contain large skeletal fragments of limestone. These soils exhibit a remarkably high organic carbon content, locally as much as Blackland Prairie soils, east of the Balcones Escarpment. Other soil units mapped nearby include members of the Speck, Purves, San Saba, Tarrant, and Volente Series (Werchan and others, 1974).

Micro-climate effects may result from the vineyard's high position on the landscape and the proximity of the drainage divide and especially the steep slopes that descend into the Barton Creek watershed north of the divide.



Explanation:

Cretaceous bedrock units

Kbk--Bull Creek Limestone (Walnut Formation

Kgr--Glen Rose Limestone

Figure 7. Bedrock--vicinity of Cana Cellars (modified from unpublished Bureau of Economic Geology mapping); Topographic map--Signal Hill Quadrangle; contour interval = 10 ft.

Explanation:
- BlD--Brackett soils, rolling (only on-site unit)
- PuC--Purves silty clay
- SaB--San Saba clay
- SpB--Speck clay loam
- TaD--Tarrant soils, rolling
- VoD--Volente complex

Figure 8. Soils--vicinity of Cana Cellars (from Werchan and others, 1974).

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APPENDIX
Summary of Wine Terms and Tasting Techniques

Common Grape Varieties

White: Chardonnay
Riesling
Semillon
Chenin Blanc
Sauvignon Blanc
Gewurztraminer
Muscat
and many others

Red: Cabernet Sauvignon
Pinot Noir
Syrah
Merlot
Cabernet Franc
Nebbiolo
Grenache
Gamay
Zinfandel
and many others

<u>On the Art and Ceremonies of Wine-tasting</u>

The following summary is abstracted from Michael Schuster's (1989) excellent "Beginner's Guide to Understanding Wine".

The Glass: Should be larger at the bottom than at the top, so as to concentrate the aroma, should hold about 1½ cups when full.

Appearance: Note 1)*clarity* (indicates absence of excessive sediment), 2) *brightness* (reflects acidity), 3) *viscosity* ("tears" or "legs" on side of glass indicating higher alcohol or sugar content), 4) *color* ("rim" -- width proportional to age and juice/skin ratio -- and "eye" -- deeper hues indicate more robust flavors;) also, with age, red wines become browner, white wines gain in color.

Smell: Different patterns (short & sharp sniffs; deep & prolonged; short & gentle; prolonged & gentle); also smell when wine is still, then after swirling, then after shaking.
A catalog of aromas: floral, fruity, spicy, nutty, woody, animal, vegetal, mineral, balsamic, chemical, charred, etc.

Taste: Four basic tastes: sweet, acid, bitter, salty, also -- astringency, body, "texture".

Procedure for Testing: Look at appearance, swirl around, then *smell* (shake if wine is "dumb" = no aroma), then take several tablespoonfuls (enough for several small swallows), swish around in mouth, observe sensations on tongue, nose, swallow a little, note aftertaste and length of finish, then spit out remainder; make notes on appearance, aroma, taste, etc.

Describing "Style": Important factors are:

1. *Acidity* -- ex: "flat, soft, lively, firm, hard";
2. *Alcohol content* -- 11% to 12% best; ex: "weak, medium-bodied, ample, heady, heavy";
3. *Tannin* -- more texture in mouth than taste; ex: "fine, supple, dry, chewy, rough, astringent;
4. *Flavor* -- ex: "fruity (what kind?), spicy (what kind?), mineral impressions (earthy, chalky, flinty, etc.), other flavors (honey, caramel, butter, nutty, etc.)"

Evaluating "quality": Important factors are:

Cleanliness (no faults);

1. Balance (of acidity, alcohol, tannin, flavor);
2. Finish (length, complexity and aroma of aftertaste);
3. Secondary aspects of quality:
    a. refinement (intensity and concentration vs. delicacy and finesse);
    b. texture (ex: smooth, round, silky, angular, coarse, rough);
    c. completeness (satisfies eye, nose, palate, with good finish).

WINE-TASTING NOTES (winery, year) ____________________

NAME, YEAR ____________________ PRICE __________ GRAPE VARIETY ____________________

Appearance:
Clarity __________
Brightness __________
Viscosity __________
Color __________
Smell: __________
____

Taste: __________
____
Style:
Acidity __________
Alcohol % __________
Tannin __________
Flavor __________

Quality:
Cleanliness __________
Balance __________
Finish __________
Refinement __________
Texture __________
Completeness __________

COMMENTS: ____________________

NAME, YEAR ____________________ PRICE __________ GRAPE VARIETY ____________________

Appearance:
Clarity __________
Brightness __________
Viscosity __________
Color __________
Smell: __________
____

Taste: __________
____
Style:
Acidity __________
Alcohol % __________
Tannin __________
Flavor __________

Quality:
Cleanliness __________
Balance __________
Finish __________
Refinement __________
Texture __________
Completeness __________

COMMENTS: ____________________

NAME, YEAR ____________________ PRICE __________ GRAPE VARIETY ____________________

Appearance:
Clarity __________
Brightness __________
Viscosity __________
Color __________
Smell: __________
____

Taste: __________
____
Style:
Acidity __________
Alcohol % __________
Tannin __________
Flavor __________

Quality:
Cleanliness __________
Balance __________
Finish __________
Refinement __________
Texture __________
Completeness __________

COMMENTS: ____________________

NAME, YEAR ____________________ PRICE __________ GRAPE VARIETY ____________________

Appearance:
Clarity __________
Brightness __________
Viscosity __________
Color __________
Smell: __________
____

Taste: __________
____
Style:
Acidity __________
Alcohol % __________
Tannin __________
Flavor __________

Quality:
Cleanliness __________
Balance __________
Finish __________
Refinement __________
Texture __________
Completeness __________

COMMENTS: ____________________

WINE-TASTING NOTES (winery, year) ____________________

NAME, YEAR ____________________ **PRICE** __________ **GRAPE VARIETY** ____________________

Appearance:
Clarity ____________
Brightness ____________
Viscosity ____________
Color ____________
Smell: ____________
____

Taste: ____________
____
Style:
Acidity ____________
Alcohol % ____________
Tannin ____________
Flavor ____________

Quality:
Cleanliness ____________
Balance ____________
Finish ____________
Refinement ____________
Texture ____________
Completeness ____________

COMMENTS: ____________________

NAME, YEAR ____________________ **PRICE** __________ **GRAPE VARIETY** ____________________

Appearance:
Clarity ____________
Brightness ____________
Viscosity ____________
Color ____________
Smell: ____________
____

Taste: ____________
____
Style:
Acidity ____________
Alcohol % ____________
Tannin ____________
Flavor ____________

Quality:
Cleanliness ____________
Balance ____________
Finish ____________
Refinement ____________
Texture ____________
Completeness ____________

COMMENTS: ____________________

NAME, YEAR ____________________ **PRICE** __________ **GRAPE VARIETY** ____________________

Appearance:
Clarity ____________
Brightness ____________
Viscosity ____________
Color ____________
Smell: ____________
____

Taste: ____________
____
Style:
Acidity ____________
Alcohol % ____________
Tannin ____________
Flavor ____________

Quality:
Cleanliness ____________
Balance ____________
Finish ____________
Refinement ____________
Texture ____________
Completeness ____________

COMMENTS: ____________________

NAME, YEAR ____________________ **PRICE** __________ **GRAPE VARIETY** ____________________

Appearance:
Clarity ____________
Brightness ____________
Viscosity ____________
Color ____________
Smell: ____________
____

Taste: ____________
____
Style:
Acidity ____________
Alcohol % ____________
Tannin ____________
Flavor ____________

Quality:
Cleanliness ____________
Balance ____________
Finish ____________
Refinement ____________
Texture ____________
Completeness ____________

COMMENTS: ____________________

SIMPLIFIED GEOLOGIC TIME SCALE

ERA	PERIOD	M.Y. AGO	IMPORTANT GEOLOGIC EVENTS
CENOZOIC	Quaternary	0-2	Ice ages; rise of *Homo sapiens*
	Tertiary	2-65	Uplift of Rocky Mountains; main activity of Balcones Fault Zone; rise of mammals
MESOZOIC	Cretaceous	65-140	Deposition of rocks in the Austin area; demise of the dinosaurs
	Jurassic	140-190	Vast salt stratum deposited across Gulf Coast Basin; first birds
	Triassic	190-250	Opening of Atlantic Ocean and Gulf of Mexico; first dinosaurs
PALEOZOIC	Permian	250-280	Final uplift of Appalachians; thick salt deposits in West Texas; massive extinctions
	Pennsylvanian	280-310	Ouachita Mountains formed; first reptiles
	Mississippian	310-345	Vast inland sea covered North America; amphibians dominant
	Devonian	345-395	Ongoing uplift of Appalachians; first amphibians; first insects
	Silurian	395-440	First land plants and air-breathing animals
	Ordovician	440-500	First stages of Appalachian uplift; vast inland sea across North America; first fishes
	Cambrian	500-570	Abrupt rise of major groups of invertebrates
PRECAMBRIAN		700	First multicellular life (sponges, jellyfish, worms)
		1100	Granites emplaced in Llano Uplift
		2000	First nucleated single-celled organisms
		3000	First blue-green algae
		4500	Continents and oceans form

ROCK UNITS ALONG FIELD TRIP ROUTE
(modified from Barnes, and others, 1972)

ERA	SYSTEM	GROUP/ SERIES	FORMATION
CENOZOIC	Quaternary		Alluvium and terrace along stream valleys
MESOZOIC	Lower Cretaceous	Edwards	Fort Terrett Limestone Comanche Peak Limestone Walnut Formation Glen Rose Limestone Hensel Sand Cow Creek Limestone Hammett Shale Sycamore Sand
PALEOZOIC	Pennsylvanian	Atoka Morrow	Smithwick Shale Marble Falls Formation
	Mississippian	Chester	Barnett Formation
	Devonian		(Seven formations - approximately 30 feet of section)
	Ordovician	Ellenburger	Honeycut Formation Gorman Formation Tanyard Formation
	Cambrian	Moore Hollow	Wilberns Formation San Saba Member Point Peak Member Morgan Creek Member Welge Sandstone Member Riley Formation Lion Mountain Sandstone Member Cap Mountain Limestone Member Hickory Sandstone Member
PRECAMBRIAN		Igneous	Llanite (Quartz Porphyry Dikes) Sixmile Granite Oatman Creek Granite Town Mountain Granite
		Meta-igneous	Metagabbro and Metadiorite Red Mountain Gneiss Red Branch Gneiss
		Metasediments	Packsaddle Schist Lost Creek Gneiss Valley Spring Gneiss

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