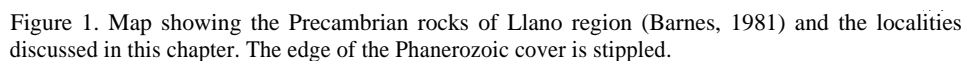


Virgil E. Barnes, Bureau of Economic Geology, University of Texas at Austin, University Station, Box X, Austin, Texas 78713-7508



“Precambrian rocks reach the surface in the Llano region of Central Texas in the highest part of a broad domal arch, the Llano uplift, which appears on a regional geologic map as an island of igneous and metamorphic rocks surrounded by Paleozoic and Cretaceous sedimentary rocks. The widest expanse of Precambrian rocks is about 65 mi (105 km), extending westward from the valley of the Colorado River through a subdued topographic basin drained by the Llano River. The broad, gentle basin carved into the Precambrian rocks is bordered by a discontinuous rim of flat-topped limestone hills which are the dissected edge of the Edwards Plateau. Within the basin and at its margins are erosional remnants and down-faulted blocks of Paleozoic rocks which form prominent hills, locally referred to as mountains.” Clabaugh and McGehee (1972, p. 9).

the Geologic Atlas of Texas, scale 1:250,000 (Barnes, 1981). On that map ‘(as well as Fig. 1), the Oatman Creek and Sixmile Granites (Table 1) are lumped as younger granitic intrusive rocky locally, in the southeast part of the Llano Sheet, the Packsaddle Schist is subdivided into four formations (McGehee, 1979). Detailed 7½-minute quadrangle maps include most of the area in which the Packsaddle Schist has been subdivided (Barnes and McGehee, 1976; 1977a, b, c).

The first significant study of the Precambrian rocks of the area was by Walcott (1884), who gave the name Llano Group to the metamorphic rocks. Mapping by U.S. Geological Survey geologists, headed by Sidney Paige (1911, 1912), led to the recognition of two major units in the Llano Group, for which he redefined names used by Comstock (1890). The lower unit is the

TABLE 1. PRECAMBRIAN STRATIGRAPHY OF THE LLANO REGION

Classification	Reference
Igneous rocks	
Llanite (quartz porphyry dikes)	Iddings, 1904
Sixmile Granite	Stenzel, 1932
Oatman Creek Granite	Stenzel, 1932
Town Mountain Granite	Stenzel, 1932
Metagneous rocks	
Metagabbro and metadiorite (not named)	Barnes, 1940
Coal Creek Serpentinite	Romberg and Barnes, 1949;
Red Mountain Gneiss	Barnes and others, 1950
Big Branch Gneiss	Barnes, 1940
Metasedimentary rocks	
Llano Group	Walcot, 1884; Llano
Packsaddle Schist	Supergroup, McGhee, 1979
Click Formation	Comstock, 1890; redefined
Rough Ridge Formation	by Paige, 1911
Sandy Formation	McGehee, 1979
Honey Formation	McGehee, 1979
Lost Creek Gneiss	McGehee, 1979
Valley Spring Gneiss	Ragland, 1960; redefined
	by Mutis-Duplat, 1982
	Comstock, 1890; redefined
	by Paige, 1911

Valley Spring Gneiss, which is chiefly microcline-quartz gneiss with subordinate biotite and hornblende. The upper unit is the Packsaddle Schist, which includes graphite schist, leptyte, marble, and amphibole schist.

West of the area mapped by Paige and others, a third unit has been identified between the Valley Spring Gneiss and the Packsaddle Schist. This unit is a distinctive augen gneiss, first noted by Barnes and others (1947, p. 121). Ragland (1960) mapped the northern occurrence of this gneiss, determined that it is metasedimentary, and named it Lost Creek Gneiss (see also Barnes and Schofield, 1964, p. 3-4). Garrison and others (1979) consider the Lost Creek Gneiss to be metarhyolitic.

Various igneous rocks intruded the Llano Group and became metamorphosed with it. Numerous bodies of serpentinite, soapstone, and other metamorphosed mafic igneous rocks, mostly south of the quadrangles mapped by Paige and others, have been mapped (Barnes, 1946, 1952a,b; Barnes and others, 1947; Clabaugh and Barnes, 1959). These rocks are discussed by Clabaugh and McGhee (1972).

Also widespread in the southern part of the region is a metamorphosed quartz diorite to which Barnes (1946) gave the name Big Branch Gneiss. Metamorphosed granite in the southeastern part of the region was recorded by Paige, and to this Romberg and Barnes (1949) assigned the name Red Mountain Gneiss. Clabaugh and Boyer (1961) found the granite gneiss to be slightly younger than the quartz diorite gneiss. The largest mafic body, Coal Creek Serpentinite; is 3.5 mi (5.6 km) long; contains amphibolite and talc schist inclusions from the Packsaddle; is cut by aplites, pegmatites, and quartz bodies derived from Town Mountain Granite; and appears to cross-cut Big Branch Gneiss (Barnes and others, 1950; Barnes, 1952a,b; Garrison and Mohr, 1984).

Large bodies of granite were intruded into the framework of folded metasedimentary rocks at the final stages of regional metamorphism. Paige distinguished two types, coarse-grained pink granite and fine-grained pink to gray granite, as well as dikes of granite porphyry and felsite. Stenzel (1932, 1935) proposed a more elaborate classification of the granites on the basis of color, grain size, and field relations. He named the oldest coarse-grained to porphyritic type Town Mountain Granite, the intermediate-age medium-grained gray to pink type Oatman Creek Granite, and the youngest fine-grained gray type Sixmile Granite.

The youngest granitic rock is a dike-like series of small irregular bodies of a distinctive granite porphyry to which Iddings (1904) gave the name llanite.

Age determinations on minerals from the Llano region were summarized by Flawn (1956, Table 4) and by Flawn and Muehlberger (1970, Table 3). Zartman (1962, 1964, 1965; Zartman and Wasserburg, 1962) made extensive determinations on whole rock samples and mineral separates from the granites and the Valley Spring Gneiss using rubidium-strontium (Rb-Sr) and potassium-argon (K-Ar) methods. Garrison and others (1979) also made Rb-Sr and K-Ar geochronologic and isotopic studies of Llano region rocks. These results indicate that the major granite bodies are $1,030 \pm 30$ million years old and the Valley Spring Gneiss is $1,120 \pm 25$ million years old. Garrison (1985) considered these Grenvillian-age rocks and their intrusions to be an island arc complex.

FIELD GUIDE SITES

Valley Spring Gneiss

Locality 1 (Fig. 2) ($98^{\circ}21'15''W.$; $30^{\circ}44'59''N.$, Longhorn Cavern $7\frac{1}{2}$ -minute Quadrangle) is along Park Road 4 about 330 ft (100 m) northwest of Spring Creek crossing in Inks Lake State Park.

The Valley Spring Gneiss is well exposed on hillsides adjacent to the eastern shore of Inks Lake. In the eastern part of the Llano region the Valley Spring Gneiss is predominantly microcline-quartz gneiss, with subordinate amounts of biotite, magnetite, epidote, and hornblende. Some layers are richer in biotite and therefore darker; a few lenses and layers are black amphibolite, but these were probably diabase dikes and other mafic igneous bodies intruded into the original rock before or during metamorphism. Farther west the Valley Spring Gneiss includes a greater variety of rocks, including one or more layers of marble (locally converted to wollastonite-garnet rock) and more numerous layers of dark schists and amphibolite. Its average composition closely approximates that of granite, whereas its distribution, layering, and structural features suggest that it was deposited as a sediment. Perhaps the simplest hypothesis of its origin is that the original rocks were ignimbrites and related rhyolitic volcanic rocks in which there were local mafic igneous rocks, calcareous tuffs, nonmarine limestone, and sediments de-

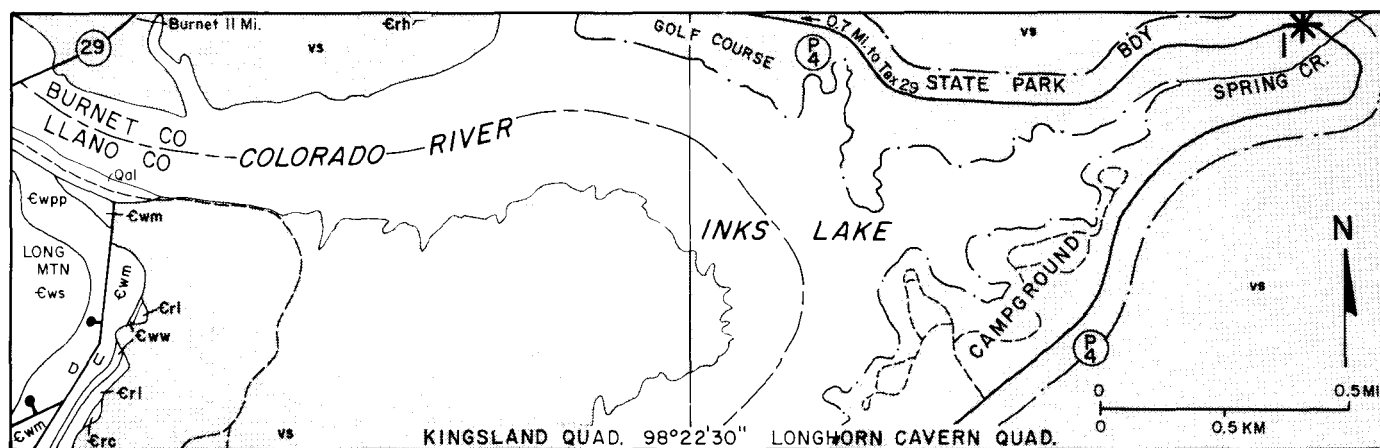


Figure 2. Geologic map of Inks Lake area, Longhorn Cavern and Kingsland Quadrangles, Burnet and Llano Counties, Texas (Barnes and McGehee, 1976). Key Alluvium, Qal; Wilberns Formation—San Saba Member, Cws; Point Peak Member, Cwpp; Morgan Creek Limestone Member, Cwm; Welge Sandstone Member, Cww; Riley Formation—Lion Mountain Sandstone Member, CrI; Cap Mountain Limestone Member, CrC; Hickory Sandstone Member, Crh; Valley Spring Gneiss, vs.

rived from the volcanic rocks. Mutis-Duplat (1982) and Droddy (1978) estimated a thickness of 12,500 ft (3.8 km) for the Valley Spring Gneiss in the western part of the Llano region.

During metamorphism some of the gneiss appears to have undergone partial melting or to have been invaded intricately by granite magma to produce complex migmatites. Following the peak of metamorphism innumerable small pegmatites, aplites, and quartz veins, probably derived from the large granite plutons, were emplaced in the gneiss as well as in other Llano Supergroup rocks.

Of the Precambrian rocks, the Valley Spring Gneiss produces the roughest topography, especially in the eastern part of the Llano region. When the Cambrian sea encroached on the Llano region, the topography was equally rough with peaks standing more than 700 ft (200 m) above the surrounding lowlands. The Morgan Creek Limestone Member of the Wilberns Formation (Cambrian) rests in places directly on the Valley Spring Gneiss (Fig. 2). Within the Kingsland quadrangle the average thickness of the Cambrian rocks beneath the Morgan Creek is 715 ft (218 m).

Lost Creek Gneiss

Locality 2 (Figs. 3, 4) (99°3'38"W.; 30°40'47"N., Art 7½-minute Quadrangle) is 6.55 mi (10.7 km) by graded road southeast of Art at the Willow Creek crossing. This locality may also be reached from U.S. 87 at Hedwigs Hill, 0.4 mi (0.6 km) north of Llano River, by following a graded road eastward 3.9 mi (6.4 km).

The Lost Creek Gneiss in this exposure is overturned, dipping about 60° eastward. Another good roadside outcrop standing 10 ft (3 m) high is 0.4 mi (0.6 km) north of Willow Creek. Also,

an almost continuous exposure is present between the road and Llano River at the windmill 0.4 mi (0.6 km) to the south. Hummocky Lost Creek Gneiss dots the broad expanse of Llano River downstream for about 0.6 mi (1 km). Outcrop continues upstream from the windmill 900 ft (300 m), at which point Lost Creek Gneiss and Packsaddle Schist are interlayered. Beyond this point outcrop is sporadic and the last one of Lost Creek Gneiss is about 600 ft (200 m) farther upstream.

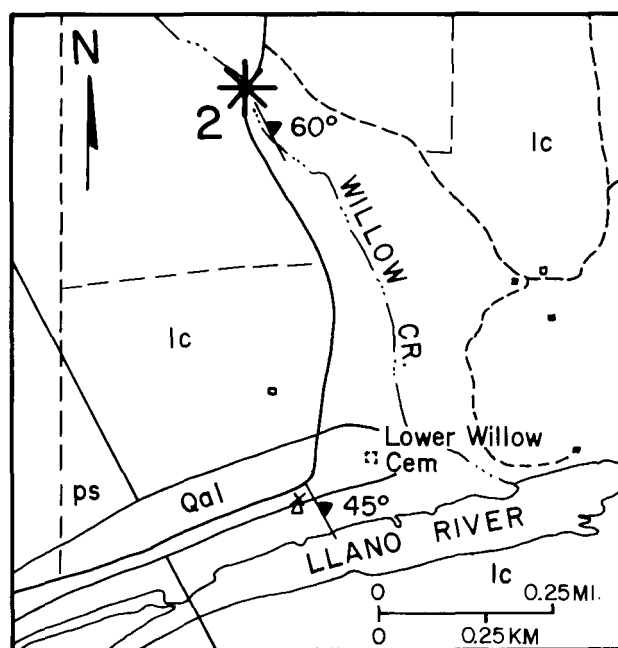


Figure 3. Geologic map of an area around mouth of Willow Creek, Art Quadrangle, Mason County, Texas (Barnes, 1981). Key: Alluvium, Qal; Packsaddle Schist, ps; Lost Creek Gneiss, lc.

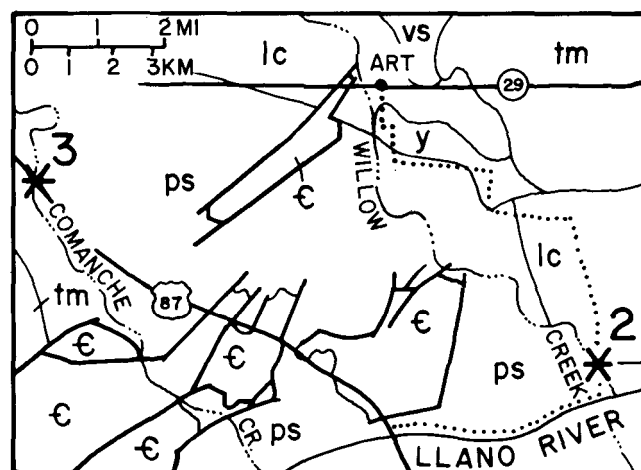


Figure 4. Geologic map of an area in central Mason County, Mason Quadrangle, Texas (Barnes, 1981). Key: Cambrian rocks, c; younger granite, y; Town Mountain Granite, tm; Packsaddle Schist, ps; Lost Creek Gneiss, lc; Valley Spring Gneiss, vs.

Mutis-Duplat (1982) described the Lost Creek Gneiss in the area he mapped as "medium- to coarse-grained, nonfoliated to very well foliated quartz-feldspar-hornblende-biotite gneiss grading into augen gneiss and migmatite." However, for most of its 2 mi (3 km) outcrop width along Llano River, the Lost Creek Gneiss is an augen gneiss with surprisingly few intrusions except near its contact with Packsaddle Schist. The original sample collected by Barnes and others (1947) is composed of quartz, oligoclase, biotite (in part altered to chlorite), a small amount of hornblende, and a little sphene deeply clouded by leucoxene; accessory minerals are magnetite, apatite, zircon, and pyrite.

Packsaddle Schist

Locality 3 (Fig. 4) ($99^{\circ}11'55''\text{W.}$; $30^{\circ}43'11''\text{N.}$, Mason 7½-minute Quadrangle) is 2.75 mi (4.5 km) southeast of Mason along U.S. 87 just short of Comanche Creek. Packsaddle Schist is exposed in a cut 10 ft (3 m) deep that extends along both sides of the highway for 0.2 mi (0.3 km). Hornblende schist and some biotite schist form most of the southeastern half of the exposure and leptyte most of the rest with some interlayering of the two. Aplite and pegmatite intrusions are numerous and both the hornblende schist and leptyte display intricate folding in places. The trace of foliation as seen on aerial photographs and a few foliation attitudes measured in the area indicate that locality 3 is on the northeastern limb of a southeastward-plunging overturned anticline.

McGehee (1979) subdivided the Packsaddle Schist in the southeastern part of the Llano region into four formations. The lower one, the Honey Formation, consists of graphite schist, marble, talc-silicate rock, leptyte, quartz-feldspar gneiss, biotite schist, hornblende schist, and muscovite schist. Next is the Sandy Formation, an alternation of quartz-feldspar rock and hornblende

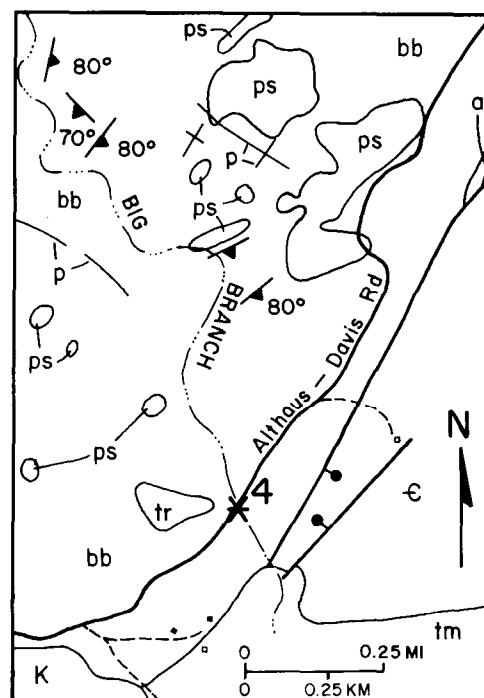


Figure 5. Geologic map of an area along Big Branch, Blowout Quadrangle, Gillespie County, Texas (Barnes, 1952 b). Key: Cretaceous rocks, K; Cambrian rocks, c; aplite, a; pegmatite, p; Town Mountain Granite, tm; Big Branch Gneiss, bb; tremolite, tr; Packsaddle Schist, ps.

schist. The third one, Rough Ridge Formation, is mostly gray quartz-feldspar rock; some muscovite schist occurs in the lower part, and some biotite gneiss with large cordierite porphyroblasts is in the upper part. The top formation, the Click Formation, has a basal member of actinolite schist, and the rest of the formation is light brown to pink leptyte and quartz-feldspar schist.

Interlayered marble and hornblende schist is well exposed in Llano County along the Click road 0.8 mi (1.3 km) southwest of Texas 71 (Barnes and McGehee, 1977c).

Big Branch Gneiss

Locality 4 (Fig. 5) ($98^{\circ}35'49''\text{W.}$; $30^{\circ}25'4''\text{N.}$, Blowout 7½-minute Quadrangle) is in eastern Gillespie County near the Blanco County line where the paved Althaus-Davis county road crosses Big Branch, from which the Big Branch Gneiss received its name. This locality is 2.5 mi (4.1 km) northeast of RR 1323 at a point 5.5 mi (8.8 km) east of Willow City. As this county-maintained unfenced road passes through private property, visitors should confine their attention to the immediate sides of the road, to avoid trespassing.

The Big Branch Gneiss is quartz diorite. It is composed of plagioclase, quartz, hornblende, biotite, magnetite, sphene, apatite, and zircon. Some samples also contain microcline, as well as the secondary minerals chlorite, epidote, and albite.

The Big Branch Gneiss is well exposed adjacent to the west side of the road where inclusions of Packsaddle Schist can be seen. One reddish aplitic intrusion, in part linear with mostly internal cross-cutting quartz veins, contains dark inclusions and in places has tilted in around breccia blocks of Big Branch Gneiss. A craggy exposure of Big Branch Gneiss along the road 0.12 to 0.18 mi (0.2 to 0.3 km) to the south is well foliated with some chevron-type deformation. The Big Branch Gneiss as a whole in this area is well foliated, and lineation pitches steeply in a direction about S10°E. Swarms of inclusions in some areas, mostly of Packsaddle Schist, are arranged parallel to the foliation. The Big Branch Gneiss has been feldspathized to augen gneiss locally near its contact with the Red Mountain Gneiss and is therefore older than the Red Mountain Gneiss (Clabaugh and Boyer, 1961).

Coal Creek Serpentinite

Locality 5 (Fig. 6) (98°37'50"W.; 30°28'59"N., Willow City and Blowout 7½-minute Quadrangles) is along a secondary road that crosses the Coal Creek Serpentinite mass. This locality is reached either by going north from Willow City 7.9 mi (13.0 km) on a paved county road or going east on the same road 4.9 mi (8.0 km) from Texas 16 at a point 18.8 mi (30.8 km) south of Llano, and then northeastward 0.4 mi (0.6 km) by a graded road. At this locality, likewise, the county-maintained road passes through private property and visitors should confine their attention to the immediate sides of the road. Permission must be obtained to visit the active quarry 0.3 mi (0.5 km) south of locality 5.

The serpentinite forms a very sparsely vegetated ridge about 3.5 mi (5.6 km) long in an east-west direction and about 0.65 mi (1 km) wide, with lobes extending northward at each end. The serpentinite mass pitches southward at an angle of approximately 45°. The original rock from which the serpentinite formed intruded Packsaddle Schist and Big Branch Gneiss, as evidenced by inclusions of both rock types in the serpentinite. The serpentinite consists dominantly of lizardite with minor magnetite, chromite, anthophyllite, and tremolite (Garrison and Mohr, 1984, Garrison, 1981).

The potential use for the serpentinite was discussed by Barnes and others (1950). Romberg and Barnes (1949), using gravity data, estimated 1010 metric tons of serpentinite to be present, of which about one billion tons is a readily available reserve.

POSTMETAMORPHIC IGNEOUS ROCKS

Town Mountain Granite

Locality 6 (Fig. 7) (98°17'55"W.; 30°35'32"N., Marble Falls 7½-minute Quadrangle) is along RR 1431 1.8 mi (2.9 km) west of U.S. 281 in Marble Falls. This locality is adjacent to a roadside park within sight of the quarry. A historical marker, situated in the park, gives the history of the Granite Mountain

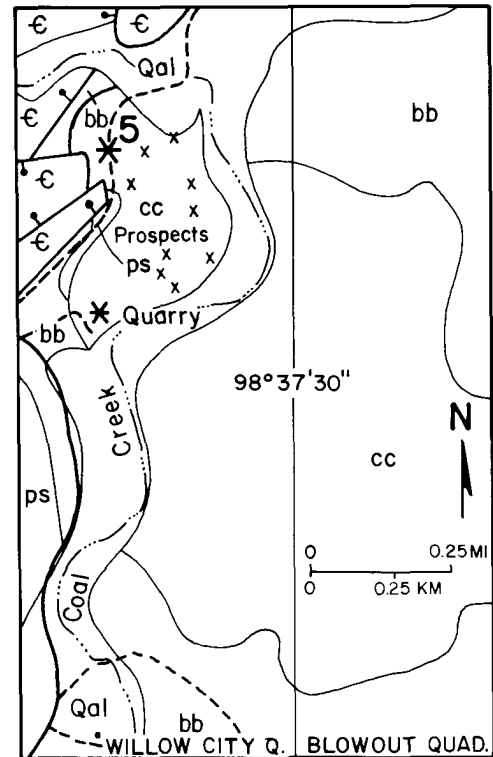


Figure 6. Geologic map of Coal Creek area near eastern end of Cutoff Gap, Willow City and Blowout Quadrangles, Gillespie County, Texas (Barnes, 1952a,b). Key: Alluvium, Qal; Cambrian rocks, €; Coal Creek Serpentinite, cc; Big Branch Gneiss, bb; Packsaddle Schist, ps.

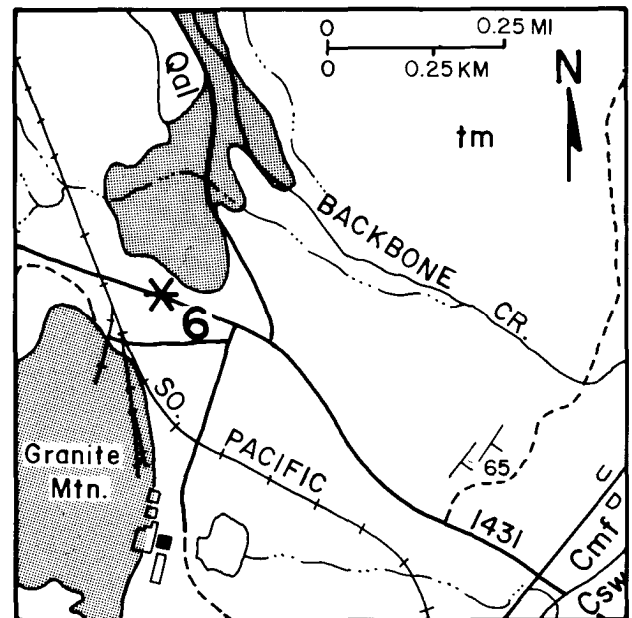


Figure 7. Geologic map of Granite Mountain area, Marble Falls Quadrangle, Burnet County, Texas (Barnes, 1982). Key: Alluvium, Qal; Smithwick Formation, Csw, Marble Falls Limestone, Cmf; Town Marble Granite (bare areas shown by stipple), tm.

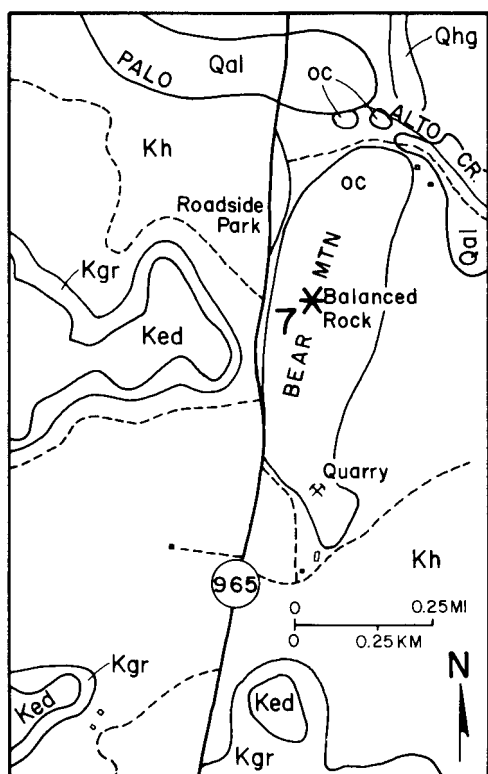


Figure 8. Geologic map of Bear Mountain area, Fredericksburg East Quadrangle, Gillespie County, Texas (Barnes, 1952c). Key: Alluvium, Qal; high gravel, Qhg; Edwards Limestone, Ked; Glen Rose Limestone, Kgr; Hensell Sand, Kh; Oatman Creek Granite, oc.

quarrying operations. A stile at the back of the park gives access to an area of bare granite from which a portion of the surface layer has been quarried, and where pegmatite veins, scarce xenoliths, and schlieren can be seen. The granite is coarsely crystalline and composed chiefly of microcline, plagioclase, and quartz, with minor amounts of biotite, hornblende, rutile, zircon, and allanite. A few of the large microcline crystals are complexly zoned and mantled by plagioclase.

This granite and the quarrying operation were described by Barnes and others (1947), and an update on quarrying methods and uses for the granite was published by Clabaugh and McGehee (1972).

Approximately 2 mi (3 km) north along the road east of locality 7, in Slaughter Gap (Barnes, 1982), Cambrian Hickory Sandstone east of the road has broken off in large blocks and is riding downslope on the decomposing Town Mountain Granite. About 0.75 mi (1.2 km) along RR 1431 to the east of locality 7 one of the major faults of the Llano region is excellently exposed, with Town Mountain Granite sharply in contact with upturned Pennsylvanian Marble Falls Limestone. The throw of the fault at this point is more than 3,300 ft (1,000 m).

For anyone interested in examining the surface of a large exfoliation dome of Town Mountain Granite, the Enchanted Rock State Natural Area in southeastern Llano County is recommended (McClay and Barnes, 1976). This area is accessible from RR 965 either by traveling 18 mi (30 km) north from Fredericksburg or west 8 mi (13 km) from Texas 16 at a point 14.7 mi (24.1 km) south of Llano County courthouse. A detailed map of the Enchanted Rock pluton (Hutchinson, 1956), of which Enchanted Rock is only a very small part, shows textural zones within the pluton and details of the metamorphic rocks into which the pluton was intruded.

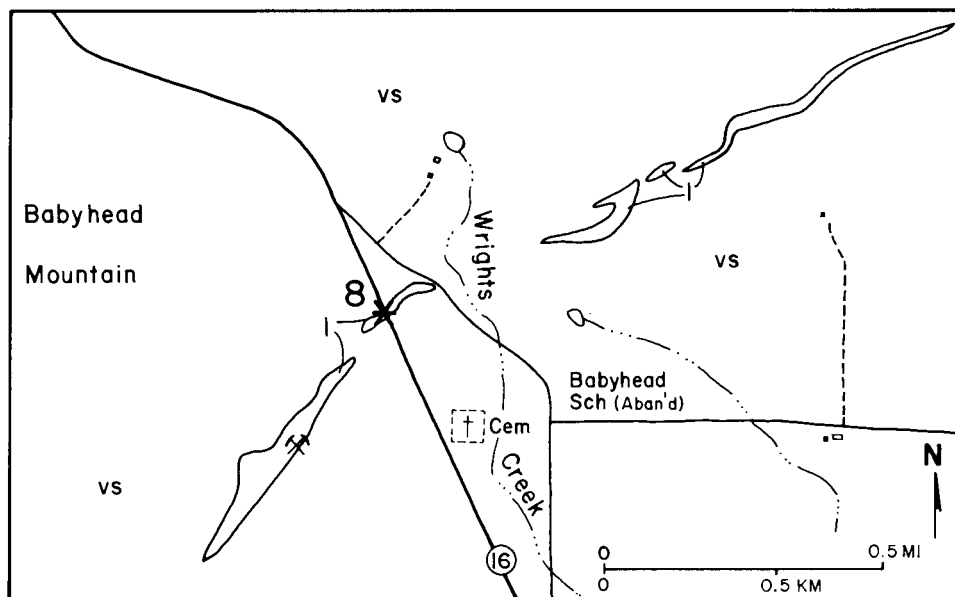


Figure 9. Geologic map of Babyhead area, Cherokee Quadrangle, Llano County, Texas (Barnes, unpublished data). Key: Llanite, l; Valley Spring Gneiss, vs.

Oatman Creek Granite

Locality 7 (Fig. 8) (98°51'24" W.; 30°19'40"N., Balanced Rock, Fredericksburg East 7½-minute Quadrangle) is 3.9 mi (6.4 km) north of U.S. 290 along the east side of RR 965. A picnic area is just north of the gap in the fence from which a marked trail leads to Balanced Rock on Bear Mountain.

The Oatman Creek granite is composed of plagioclase, microcline, quartz, and biotite, with a small amount of magnetite, fluorite, and apatite. The granite at Bear Mountain, used chiefly as a monumental and decorative stone, has been quarried for many years (Barnes and others, 1947; Barnes, 1952c). The surface of Bear Mountain is littered with large exfoliation boulders of granite. Balanced Rock, about 8 ft (2.4 m) in diameter, is now one of those boulders. It was blasted from its pedestal by vandals during the spring of 1986. Bear Mountain is a pre-Cretaceous monadnock that stands as high as the surface of the adjacent Edwards Plateau. About 180 ft (54 m) of the monadnock has been exhumed; the amount that remains buried is unknown.

An excellent overview of Enchanted Rock and the Llano basin can be obtained from the edge of the Edwards Plateau by continuing northward from Bear Mountain 10.2 mi (16.7 km).

Quartz-Feldspar Porphyry (Llanite) Dikes

Locality 8 (Fig. 9) (98°39'30"W.; 30°53'26"N., Cherokee 7½-minute Quadrangle) is in a cut at the crest of a sharp boulder-strewn ridge crossing Texas 16 east of Babyhead Mountain, Llano County (Barnes, unpublished data). The locality is 9.0 mi (14.4 km) north of the intersection of Texas 16 and 29 in Llano.

The porphyry (Iddings, 1904) is one of the youngest granitic rocks in the Llano region and forms a dike-like series of small irregular bodies of a distinctive quartz-feldspar porphyry that extends eastward from the area shown in Figure 9 to near Little Llano River, then southward to the Llano-Lone Grove road, a total of about 14 mi (22 km). The porphyry is characterized by phenocrysts of red feldspar and blue chatoyant quartz in a dark aphanitic groundmass. In the past the llanite from the quarry 0.3 mi (0.5 km) southwest of locality 8, marketed under the name opaline granite, was used as a monumental and ornamental stone. The llanite has a crushing strength of 37,800 pounds per square inch and is the strongest stone tested in the Llano region.

REFERENCES CITED

- Barnes, V. E., 1940, Precambrian of Llano region with emphasis on tectonics and intrusive: Geological Society of America, Guidebook to Excursions in Connection with 53rd Annual Meeting, Austin, Texas, p. 44-55.
- , 1946, Soapstone and serpentine in the Central Mineral Region of Texas: University of Texas Bureau of Economic Geology Publication 4301, p. 55-92.
- , 1952a, Geology of the Willow City Quadrangle, Gillespie and Llano Counties, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 4.
- , 1952b, Geology of the Blowout Quadrangle, Gillespie, Blanco, and Llano Counties, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 5.
- , 1952c, Geology of Palo Alto Creek Quadrangle, Gillespie County, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 8.
- , 1981, Geologic Atlas of Texas-Llano Sheet: University of Texas Bureau of Economic Geology.
- , 1982, Geology of the Marble Falls Quadrangle, Burnet and Llano Counties, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 48.
- unpublished data (on photograph CJC-6-138, USDA SCS): University of Texas Bureau of Economic Geology files.
- Barnes, V. E., and McGehee, R. V., 1976, Geology of the Kingsland Quadrangle, Llano and Burnet Counties, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 41.
- , 1977a, Geology of the Click Quadrangle, Llano and Blanco Counties, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 43.
- , 1977b, Geology of the Dunman Mountain Quadrangle, Llano, Burnet, and Blanco Counties, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 44.
- , 1977c, Geology of the Cap Mountain Quadrangle, Llano County, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 45.
- Barnes, V. E., and Schofield, D. A., 1964, Potential low-grade iron ore and hydraulic-fracturing sand in Cambrian sandstones, northwestern Llano region, Texas: University of Texas Bureau of Economic Geology Report of Investigations 53, 85 p.
- Barnes, V. E., Dawson, R. F., and Parkinson, G. A., 1947, Building stones of central Texas: University of Texas Bureau of Economic Geology Publication 4246, 198 p.
- Barnes, V. E., Shock, D. A., and Cunningham, W. A., 1950, Utilization of Texas serpentine: University of Texas Bureau of Economic Geology Publication 5020, 52 p.
- Clabaugh, S. E., and Barnes, V. E., 1959, Vermiculite in central Texas: University of Texas Bureau of Economic Geology Report of Investigations 40, 32 p.
- Clabaugh, S. E., and Boyer, R. E., 1961, Origin and structure of the Red Mountain Gneiss, Llano County, Texas: Texas Journal of Science, v. 13, p. 7-16.
- Clabaugh, S. E., and McGehee, R. V., 1972, Precambrian rocks of Llano region, in Barnes, V. E., Bell, W. C., Clabaugh, S. E., Cloud, P. E., Jr., McGehee, R. V., Rodda, P. U., and Young, K., 1972, Geology of the Llano region and Austin area: University of Texas Bureau of Economic Geology Guidebook 13, p. 9-23.
- Comstock, T. B., 1890, A preliminary report on the Central Mineral Region of Texas: Austin, Geological Survey of Texas, First Annual Report, p. 239-391.
- Droddy, M. J., 1978, Metamorphic rocks of the Fly Gap Quadrangle, Mason County, Texas [Ph.D. thesis]: Austin, University of Texas.
- Flawn, P. T., 1956, Basement rocks of Texas and southeast New Mexico: University of Texas Bureau of Economic Geology Publication 6505, 261 p.
- Flawn, P. T., and Muehlberger, W. R., 1970, The Precambrian of the United States of America; South-Central United States, in The Geologic Systems, The Precambrian: Interscience, v. 4, p. 72-143.
- Garrison, J. R., Jr., 1981, Coal Creek serpentinite, Llano uplift, Texas: A fragment of an incomplete Precambrian ophiolite: Geology, v. 9, p. 225-230.
- , 1985, Petrology, geochemistry, and origin of the Big Branch and Red Mountain Gneisses, southeastern Llano uplift, Texas: American Mineralogist, v. 70, p. 1151-1163.
- Garrison, J. R., Jr., and Mohr, D., 1984, Geology of the Precambrian rocks of the Llano uplift, central Texas: Austin Geological Society Guidebook 5, 58 p.
- Garrison, J. R., Jr., Long, L. E., and Richmann, D. L., 1979, Rb-Sr and K-Ar geochronologic and isotopic studies, Llano uplift, central Texas: Contributions to Mineralogy and Petrology, v. 69, p. 361-374.
- Hutchinson, R. M., 1956, Structure and petrology of Enchanted Rock batholith, Llano and Gillespie Counties, Texas: Geological Society of America Bul-

- letin, v. 67, p. 763-806.
- Iddings, J. P., 1904, Quartz feldspar porphyry from Llano, Texas: *Journal of Geology*, v. 12, p. 225-231.
- McClay, R., and Barnes, V., 1976, Field trip road log stops 1-5, October 30, in *Economic Geology of South-Central Texas*: San Antonio, South Texas Geological Society, p. 6-35.
- McGehee, R. V., 1979, Precambrian rocks of the southeastern Llano region, Texas: University of Texas Bureau of Economic Geology Geological Circular 79-3, 36 p.
- Mutis-Duplat, E., 1982, Geology of the Purdy Hill Quadrangle, Mason County, Texas: University of Texas Bureau of Economic Geology Geologic Quadrangle Map 52.
- Paige, S., 1911, Mineral resources of the Llano-Burnet region, Texas: U.S. Geological Survey Bulletin 450, 103 p.
- , 1912, Description of the Llano and Burnet Quadrangles U.S. Geological Survey Atlas, Llano-Burnet Folio, no. 183, 16 p.
- Ragland, P. C., 1960, Geochemical and metrological studies of the Lost Creek Gneiss, Mason and McCulloch Counties, Texas [M.S. thesis]: Rice University, 99 p.
- Romberg, F., and Barnes, V. E., 1949, Correlation of gravity observations with geology of the Coal Creek serpentine mass, Blanco and Gillespie Counties, Texas: *Geophysics*, v. 14, p. 151-161.
- Stenzel, H. B., 1932, Precambrian of the Llano uplift, Texas: Geological Society of America Bulletin, v. 43, p. 143-144.
- , 1935, Precambrian structural conditions in the Llano region, in *The Geology of Texas*, v. II, Structural and Economic Geology University of Texas Bureau of Economics Geology Bulletin 3401, p. 74-79.
- Walcott, C. D., 1884, Notes on Paleozoic rocks of central Texas: *American Journal of Science*, 3rd ser., v. 28, p. 431-433.
- Zartman, R. E., 1962, $\text{Rb}^{87}\text{-Sr}^{87}$ and $\text{K}^{40}\text{-Ar}^{40}$ ages of Precambrian rocks from the Llano uplift, Texas: Geological Society of America Program, 1962 Annual Meetings, p. 166A-167A.
- , 1964, A geochronologic study of the Lone Grove pluton from the Llano uplift, Texas: *Journal of Petrology*, v. 5, p. 359-408.
- , 1965, Rubidium-strontium age of some metamorphic rocks from the Llano uplift, Texas: *Journal of Petrology*, v. 6, p. 28-36.
- Zartman, R. E., and Wasserburg, G. J., 1962, A geochronologic study of a granite pluton from the Llano uplift, Texas [abs.]: *Journal of Geophysical Research*, V. 67, p. 1664.

ACKNOWLEDGMENTS

I thank C. D. Henry and J. G. Price for their painstaking and helpful review of the manuscript for this chapter of the Guidebook.