Precambrian Rocks in the Cordes Area, Yavapai County, Arizona

GEOLOGICAL SURVEY BULLETIN 1345

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By C. A. ANDERSON

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A study of the stratigraphy and structure of the Precambrian stratified and intrusive rocks

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PRECAMBRIAN ROCKS IN THE CORDES AREA, YAVAPAI COUNTY, ARIZONA

By C. A. Anderson

ABSTRACT

The Precambrian rocks in the Cordes area are in large part southern extensions of rocks exposed to the north in the NW¼ Mayer quadrangle, except that the plutons are petrologically different. The stratified Precambrian rocks are largely volcanic and volcaniclastic and are assigned to the Spud Mountain Volcanics and younger Iron King Volcanics in the Big Bug Group of the Yavapai Series.

The Spud Mountain Volcanics comprises an upper unit, a lower unit, and large masses of quartz porphyry. The lower unit consists of andesitic breccia, mixed andesitic-rhyolitic fine-textured tuffaceous sediments, ferruginous chert beds, amygdaloidal andesitic-basaltic flows, and widespread rhyolitic flows, tuffs, and intrusive masses. The upper unit is dominated by sandy and silty beds that are metamorphosed to the greenschist facies in the northern part of the area and show increase in metamorphic grade southward to garnet- and staurolite-bearing mica schists. The quartz porphyry, which is limited to the Spud Mountain Volcanics, represents shallow intrusives or protrusive domes developed during the volcanic cycles.

The Iron King Volcanics is dominated by a sequence of amygdaloidal mafic flows. The lower part of the volcanics contains many inclusions of chert and limestone and is separated from the upper flows by a wedge of ferruginous chert. Rhyolitic flows and tuffs locally intertongue with the upper flows.

In the eastern part of the area, Precambrian intrusive rocks include early quartz diorite porphyry, foliated in part and intruded by the Bumblebee Granodiorite. A few large masses of gabbro form roof pendants in, or marginal to, the Badger Spring Granodiorite, which is intrusive into the Bumblebee Granodiorite. Coarse-grained Crazy Basin Quartz Monzonite is exposed in the southwestern corner of the area and forms the northern end of a large pluton widely exposed to the south. Two small plugs of granodiorite porphyry intrude the Spud Mountain Volcanics.

Rhyolite porphyry dikes and plugs of Late Cretaceous or early Tertiary age are abundant west and northwest of the Cordes area but are limited to a few outcrops in the southwestern corner of this area.

The Cenozoic rocks include the Hickey Formation of Miocene and Pliocene age, which consists of olivine basalt flows with intertonguing gravels and sands. Younger sediments include reddish gravels along the tributaries to the larger streams; terrace deposits and river wash are locally significant along the major streams.

The Shylock fault zone, a major Precambrian structure of the region, separates the Precambrian rocks of the Cordes area into two blocks. The zone is exposed for a distance of 45 miles and has a minimum of 5 miles of right-lateral slip. It is about 1 mile wide in the Cordes area and contains quartz porphyry and Spud Mountain Volcanics as large fault slices associated with local slices of gabbro and Badger Spring Granodiorite. In the northwestern part of the block west of the zone, the Iron King Volcanics and upper unit of the Spud Mountain Volcanics form the eastern limb of a major overturned syncline. In the southwestern corner, the Spud Mountain Volcanics has been split and jammed northward by the pluton of Crazy Basin Quartz Monzonite, as reflected by the bedding and foliation wrapping around the pluton and associated northward plunge of many minor fold axes. The block east of the fault zone is dominated by the Bumblebee and Badger Spring Granodiorites, but roof pendants of Spud Mountain Volcanics reveal bedding structures that suggest northward-trending folds.

The Blue Bell massive sulfide ore body is the major Precambrian ore deposit in the Cordes area. Active mining was largely from 1896 to 1926; $14 million worth of gold, silver, and copper was produced. A Precambrian gold-quartz vein has a production record of $20,000. The other ore deposits are probably Late Cretaceous or early Tertiary; they are clustered in the southwestern corner of the area. These deposits are low-dipping vuggy quartz veins containing base metals and silver. Production has been small.

INTRODUCTION

The Cordes area of central Arizona, so called for the small settlement of Cordes in the center of the eastern half of the area, is part of the Mayer 15-minute quadrangle, which covers the northeastern part of the Bradshaw Mountains (fig. 1). The area of this report is the SW¼ of the Mayer quadrangle. The base for the geologic map (pl. 1) has been enlarged from the topographic series to a scale of 1:24,000.

Previous studies of the Precambrian rocks in the region north and northwest of the Bradshaw Mountains have been made in the Prescott quadrangle (Krieger, 1965) and the Mingus Mountain quadrangle (Anderson and Creasey, 1958). The northern part of the Bradshaw Mountains has been mapped in the NE¼ Mount Union quadrangle, the NW¼ Mayer quadrangle (Anderson and Blacet, 1972a), and the SE¼ Mount Union quadrangle (Blacet, 1968).

The Precambrian rocks shown on the geologic map (pl. 1) are in large part southern extensions of rocks exposed to the north in the NW¼ Mayer quadrangle (Anderson and Blacet, 1972a, pl. 2),

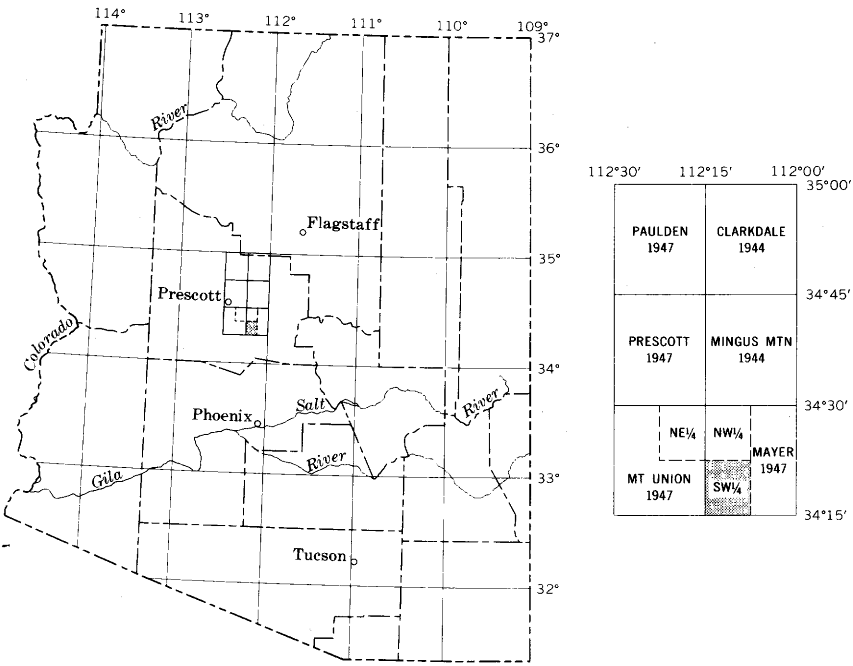

FIGURE 1.—Index map of Arizona showing location of the Cordes area, SW¼ Mayer quadrangle. Geologic maps of adjacent areas have been published: Paulden and Prescott quadrangles (Krieger, 1965), Mingus Mountain quadrangle (Anderson and Creasey, 1958, 1967), Clarkdale quadrangle (Lehner, 1958), NE¼ Mount Union and NW¼ Mayer quadrangles (Anderson and Blacet, 1972a), Mount Union quadrangle (Anderson and Blacet, 1972b), Mayer quadrangle (Anderson and Blacet, 1972c).

except that the plutons are petrologically different. The metamorphosed stratified rocks extend south of the Cordes area for about 18 miles, forming a belt of schist that separates a large north-trending pluton to the west from a cover of Tertiary volcanic and sedimentary rocks to the east (Jerome, 1956). The Cordes area includes the northern part of this "schist belt."

The first adequate description of the Precambrian rocks in the Bradshaw Mountains was by Jaggar and Palache (1905), and it is a pleasure to report the overall excellence of their reconnaissance survey. An important work on the ore deposits is one by Lindgren (1926) that contains a wealth of information on the mines and prospects.

Acknowledgments.—My colleague, P. M. Blacet, assisted me in some of my earlier studies of the Precambrian geology in this

general region, and mapped independently the adjacent SE¼ Mount Union quadrangle. Our numerous discussions on the regional and local geology have been of great value in clarifying the complexities of the Precambrian geology of the Cordes area.

PRECAMBRIAN ROCKS

YAVAPAI SERIES

The Precambrian stratified rocks in this general region were assigned to the Yavapai Series by Anderson and Creasey (1958), who recognized two groups in the Mingus Mountain quadrangle—the Ash Creek and the Alder—separated by the Shylock fault. Subsequent isotopic dating has proven that the Ash Creek Group is older and that rocks previously assigned to the Alder Group in the Jerome and Prescott areas should be renamed the Big Bug Group. In the Cordes area, the Big Bug Group is present on both sides of the Shylock fault zone but the Ash Creek Group is not exposed. Isotopic dating makes it possible to use the name Yavapai Series as a time-stratigraphic term in a provincial sense, and the Yavapai Series is defined as rocks of the time interval 1,770±10 m.y. (million years) to 1,820+m.y. (Anderson and others, 1971).

The stratified rocks composing the Yavapai Series are dominantly of volcanic origin, and most of the bedded clastic rocks consist of volcanic detritus. In general, relict textures and structures are sufficiently preserved to determine the character of the rocks prior to metamorphism, and the prefix "meta" is not used in the stratigraphic nomenclature. Most of the rocks in the Yavapai Series are in the greenschist facies of metamorphism, but in the southern part of the Cordes area, quartz-mica schists locally containing garnet and staurolite are present near the Crazy Basin Quartz Monzonite and relict textures are largely destroyed.

BIG BUG GROUP

Two formations of the Big Bug Group are present in the Cordes area, the Spud Mountain Volcanics and younger Iron King Volcanics. In the Mount Union and Prescott quadrangles, to the north and northwest, the Green Gulch Volcanics, which is older than the Spud Mountain Volcanics, contains a large volume of pillow and amygdaloidal mafic flows. The total thickness of the Big Bug Group to the north of the Cordes area is estimated as approximately 20,000 feet.

SPUD MOUNTAIN VOLCANICS

The Spud Mountain Volcanics is divided into two stratigraphic units and masses of quartz porphyry. In the Cordes area the lower unit is dominated by rhyolitic flows, breccias and tuffs, and intrusive masses separated by a sequence of mixed andesitic and rhyolitic tuffaceous rocks containing interbeds of chert. Amygdaloidal andesitic and basaltic flows are widely distributed through this complex of intertonguing rhyolitic and andesitic rocks. In the type locality of Spud Mountain Volcanics in the northeastern corner of the Mount Union quadrangle, andesitic breccia is the dominant element in the lower unit; in the Cordes area, its distribution is limited.

The upper unit in the Cordes area consists largely of metamorphosed sandstone, siltstone, and shale, recrystallized to mica schists near the Crazy Basin Quartz Monzonite. The andesitic tuffaceous rocks that dominate the upper unit in the northern part of the Mayer quadrangle (Anderson and Blacet, 1972a) are of limited distribution in the Cordes area, where they are confined to the basal part of the upper unit.

LOWER UNIT

ANDESITIC BRECCIA

Three small exposures of andesitic breccia surrounded by the Tertiary Hickey Formation crop out at the northern margin of the Cordes area (pl. 1). Other small outcrops of breccia occur east of Cedar Creek (pl. 1, 1,218,000 N., 414,300 E., and 417,300 E.; 1,204,000 N., 411,000 E., and 413,200 E.). The largest outcrop is on Cordes Peak; four other outcrops are to the east and northeast of Cordes Peak. The most southerly outcrop of the area mapped is in the southeastern corner (pl. 1, 1,183,500 N., 434,000 E.).

Porphyritic andesite is the major rock type forming clasts in the breccia; the plagioclase phenocrysts, generally 4 to 8 mm (millimeters) long, are appreciably saussuritized and are commonly arranged in clusters. The groundmass is gray to dark gray. Vesicular and amygdaloidal andesitic clasts are present in places. Clasts of rhyolite are common but may be absent in some beds and abundant in others. The rhyolitic clasts are light colored and felsitic, locally containing small (0.5 to 1 mm) phenocrysts of quartz and feldspar.

The matrix of the breccia is composed largely of granule to fine sand lithic clasts of andesite associated with angular to equant-shaped saussuritized plagioclase grains. In beds containing

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rhyolitic debris, the matrix contains small clasts of quartz and groundmass chips of rhyolite.

The more southerly outcrops of andesitic breccia exposed east of Cedar Creek contain some greenish amphibole associated with chlorite and a few minute flakes of biotite. The phenocrysts are albitic and are speckled with sericite; the calcium-bearing minerals, clinozoisite and calcite, are largely in the groundmass. Clasts in the breccia from Cordes Peak contain sharply twinned oligoclase phenocrysts dusted with small amounts of clinozoiste. Epidote, clinozoisite, chlorite, and pale-green amphibole separate microlites of feldspar and sparse quartz in the groundmass.

Andesitic and Basaltic Flows

Mafic lava flows that range from basalt to andesite in composition are largely limited to the lower unit of the Spud Mountain Volcanics in the Cordes area (pl. 1). To the east and southeast of Cleator, however, mafic flows intertongue with the bedded sedimentary rocks of the upper unit (pl. 1), and one flow associated with chert crops out near the top of this sedimentary sequence, less than half a mile east of the Jubilee mine (pl. 1).

The mafic flows in the lower unit intertongue with andesitic breccia, rhyolitic breccia and flows, and fine-grained tuffaceous rocks in the belt of Precambrian rocks extending east-northeast of Cedar Creek (pl. 1), where these rocks are covered to the north and south by the Tertiary Hickey Formation. Southward, the mafic flows are west of and within the Shylock fault zone. The larger exposures of mafic flows are east and northeast of Cordes at the margins of the various plutonic rocks. One small exposure of the mafic flows crops out on the north side of Bumblebee Creek at the southern margin of the area (pl. 1, 434,500 E.).

The mafic flows generally form conspicuous greenish to dark-gray outcrops and exhibit obvious amygdaloidal and vesicular structures except in the highly foliated facies within the Shylock fault zone. In some outcrops, grayish-white saussuritized plagioclase phenocrysts 2 to 3 mm long stand out against the dark groundmass, but in general, feldspar phenocrysts are absent or are not recognizable in the outcrop.

Studies in thin section reveal that some of the plagioclase phenocrysts are small, 0.2 to 0.5 mm in length, and that nearly all the phenocrysts are heavily charged with clinozoisite, separated by alkalic feldspar, quartz, and granules of epidote and (or) clinozoisite. Chlorite is common in samples from the northern exposures and in the foliated facies from the Shylock fault zone. Many of the foliated flows contain an appreciable amount of quartz associated with the chlorite. Calcite is common, particularly as vesicle fillings. In the southern and eastern exposures greenish hornblende is conspicuous in some samples and biotite is rare. Sphene, apatite, and magnetite are common accessories. Northeast of Cordes, quartz-epidote zones are locally present.

A chemical analysis (table 1, sample 1) of an amygdaloidal basalt exposed east of Cedar Creek in the northern part of the area of plate 1, gives 4.1 percent H_2O+, reflecting the high content of chlorite, and 3.2 percent CO_2, indicating calcite. A silica content of about 50 percent, obtained by recalculating the analyses by subtracting H_2O+ and CO_2, indicates a basaltic character. Chemical analyses of other mafic volcanic rocks in the Spud Mountain Volcanics have been published (Anderson and Blacet, 1972a).

TABLE 1.—*Chemical analyses of lavas in lower unit of the Spud Mountain Volcanics*

[Rapid rock analyses by Paul Elmore, Lowell Artis, S. D. Botts, G. W. Chloe, J. L. Glenn, James Kelsey, Hezekiah Smith, and D. Taylor]

	1	2	3	4
SiO_2	47.8	73.6	75.3	77.6
Al_2O_3	16.5	14.4	12.2	13.2
Fe_2O_3	1.7	.60	.56	.19
FeO	9.0	2.0	2.4	.64
MgO	5.7	.59	.47	.48
CaO	5.9	1.2	1.5	.22
Na_2O	4.1	5.6	4.7	5.5
K_2O	.15	.22	1.2	.07
H_2O-	.12	.03	.05	.05
H_2O+	4.1	1.0	.85	.76
TiO_2	.72	.44	.25	.34
P_2O_5	.38	.12	.02	.02
MnO	.37	.04	.12	.02
CO_2	3.2	$<.05$	.08	$<.05$
Sum	100	100	100	99
Powder density	2.88		2.70	
Bulk density	2.74		2.65	

1. Amygdaloidal basalt, 1,215,200 N., 412,200 E.
2. Flow-banded rhyolite, 1,205,900 N., 426,700 E.
3. Flow-banded rhyolite 1,204,200 N., 429,700 E.
4. Rhyolite, 1,192,900 N., 418,300 E.

RHYOLITIC ROCKS

The rhyolitic rocks of the lower unit of the Spud Mountain Volcanics are exposed in a north-trending belt west of and within the Shylock fault zone (pl. 1). In general, these rhyolitic rocks are more or less foliated. Nonfoliated rhyolitic rocks of this unit are exposed on the lower slopes of Cordes Peak and north and northeast of the peak; their map pattern indicates that much of the rhyolite is intrusive, as the masses cut across the structural trends of the andesitic breccia and mafic flows (pl. 1). To the north in the NW¼ Mayer quadrangle, the easterly outcrops of rhyolite in the lower unit are also intrusive masses (Anderson and Blacet, 1972a).

Flow-banded rhyolite exposed north of Cordes Peak (pl. 1, 1,210,500 N., 428,000 E.) is concordant with the structural trend of the associated mafic flows and may be a lava flow. A lenticular mass of rhyolite in the northern part of the Shylock fault zone (pl. 1, 1,121,000 N., 413,000 E.) that exhibits flow-banding on its western margin may be a thick lava flow or series of thinner flows. South of the lava mesa covering the Shylock fault zone, vesicular facies of rhyolite crop out, indicating flow material (pl. 1, 1,199,200 N., 413,000 E.).

Relict textures and structures are obscure in many of the outcrops within or to the west of the Shylock fault zone, because of the pervasive foliation, but are revealed in some water-worn exposures in the stream canyons. In general, the rhyolitic rocks in this zone show fragmental structures, indicating that in part they may be flow breccias, but they more probably are bedded breccias. In the canyon of Turkey Creek, north of Townsend Butte, beds of volcanic breccia are well exposed. Some of the beds are 30 feet thick and contain clasts a foot long, but most are thinner and contain clasts 2.5 to 7.5 cm (centimeters) long. In some, the matrix between the rhyolitic clasts is composed of chlorite and hornblende, indicating an admixture of mafic volcanic debris. Locally mafic pyroclastic interbeds that measure as much as 100 feet in thickness contain volcanic bombs separated by fine-grained mafic and rhyolitic clasts.

In Turkey Creek, south of Townsend Butte (pl. 1, 1,188,000 N.), rhyolitic breccia is exposed; some of the clasts contain quartz phenocrysts, 2 to 3 mm in diameter, resembling some of the quartz porphyry that is intrusive into this rhyolitic sequence. The character of the "quartz porphyry" clasts indicates that their source may be adjacent intrusive quartz porphyry that by explosive eruption or erosion supplied debris to the rhyolitic breccias.

North of Townsend Butte, the western exposures of the rhyolitic rocks of the lower unit reveal excellent bedding in sandy tuffaceous beds. The western boundary of the lower unit has been placed where the ferruginous chert beds crop out (pl. 1, 1,197,000 N., 409,500 E.).

The rhyolitic rocks of the lower unit range from light gray to greenish gray to tan, except along the eastern margin of the Shylock fault zone, where they are strongly foliated and heavily stained with limonite. The more massive rhyolitic rocks generally contain albitic phenocrysts 0.5 to 1.5 mm long that may or may not be associated with quartz phenocrysts of the same dimension. The groundmass is predominantly microgranular quartz and alkalic feldspar; rarely is K-feldspar revealed by staining. Sericite, chlorite, and green to brown biotite appear in the groundmass of many samples, and apatite is a common accessory. Where the rocks are foliated, the micaceous minerals generally show a parallel orientation.

The rhyolitic rocks from the western exposures commonly contain appreciable chlorite and (or) greenish amphibole associated with greenish to brown biotite; this reflects the mafic volcanic admixture in the clastic rocks.

Much of the rhyolite north of Cordes Peak has a flinty appearance. Thin sections reveal albitic and quartz phenocrysts, 0.1 to 0.2 mm in size, embedded in a patchy microcrystalline groundmass of quartz, albitic plagioclase, and sparse K-feldspar. Some of the plagioclase is in spherulitic aggregates, suggesting that the rhyolite may have had a glassy base that has devitrified. These rhyolitic masses are probably intrusive bodies, and the relict texture indicates a very shallow depth of emplacement, or they may have risen to the surface as protrusive domes at the time of formation.

Mixed Andesitic and Rhyolitic Rocks

The mixed andesitic and rhyolitic rocks contain much volcanic detritus and form light- to medium-green foliated rocks (pl. 1). Locally many thin chert beds are present. These mixed rocks crop out east of the Shylock fault zone (pl. 1, 1,220,000 N., 420,000 E.) and within the Shylock fault zone south of the lava mesa (pl. 1, 1,202,000 N., 414,500 E.). Narrow disconnected outcrops of quartz porphyry, mafic flows, gabbro, and Badger Spring Granodiorite within the fault zone probably are fault slices, and many of the internal contracts between the different facies may be fault contacts.

Original bedding structures are exposed in a sufficient number of outcrops to demonstrate that these mixed rocks were of sedimentary origin, and the grain size ranges from clasts 2.5 cm (centimeters) long to silt size. Chips of mafic lava and rhyolite are common as well as angular clasts of albitic plagioclase and quartz. Some aggregates of sericite suggest original rhyolitic pumice, now collapsed and recrystallized. Sericite and chlorite are the common minerals in the fine-grained foliated rocks; abundant sericite reflects a high content of rhyolitic detritus and abundant chlorite reflects a high content of mafic volcanic detritus. Most of the rocks contain these micaceous minerals in more or less equal amounts. Tiny flakes of greenish biotite appear in the northern exposures and greenish to brown biotite is present in small amounts in the southerly exposures. Leucoxene grains are common where the chlorite content is appreciable, and calcite grains are sporadically present.

The mixed andesitic and rhyolitic rocks are exposed in the NW¼ Mayer quadrangle, where they are thinly bedded sandstone and siltstone containing numerous thin interbeds of fine to coarse volcanic breccia. Intertongueing of these mixed rocks with the dominant andesitic breccia indicates that this assemblage of finer textured volcaniclastic rocks is an intergral part of the breccia facies of the lower unit (Anderson and Blacet, 1972a). Southward in the NW¼ Mayer quadrangle, the fine-textured tuffaceous rocks have been pervasively altered except near the southern margin of the quadrangle where they extend into the Cordes area (pl. 1, 418,000 E.).

Ferruginous Chert

Ferruginous chert beds (pl. 1) are sporadically distributed through the lower unit of the Spud Mountain Volcanics and generally form conspicuous black outcrops. Layers of magnetite and (or) hematite are present in the thin chert beds, which are separated by interleaves of highly foliated sericitic and chloritic rocks.

The most northerly exposures of the ferruginous cherts are in the Shylock fault zone (pl. 1, 1,217,000 N., 415,000 E.; 1,211,000 N., 414,500 E.) and are spatially associated with the mafic flows or rhyolitic rocks. The thickest section, 300 feet wide and, also within the Shylock fault zone, is exposed south of the lava mesa (pl. 1, 1,198,000 N., 414,000 E.) and intertongues with the mixed andesitic and rhyolitic tuffaceous rocks and the mafic flows. In this general area, short disconnected lenses of ferruginous chert crop out to the east in the mixed andesitic tuffaceous rocks. A swarm of ferruginous chert beds in some of the quartz porphyry masses east and south-southeast of Townsend Butte (pl. 1) may be fault slivers within the Shylock fault zone. The most continuous exposures of the ferruginous chert beds crop out west of Townsend Butte at the contact with the upper unit of the sedimentary rocks.

Excellent exposures of ferruginous chert crop out south of Townsend Butte 1 mile east of Cleator; these chert beds have been explored by an adit and inclined shaft (pl. 1, St. Johns mine). The U.S. Bureau of Mines (Harrer, 1964) has sampled the chert beds and determined the content of iron and manganese (table 2). Spectrographic analyses indicate 0.01 to 0.1 percent cobalt, nickel, and copper and 0.001 to 0.01 percent vanadium (Harrer, 1964, p. 106).

TABLE 2.—*Partial chemical analyses of ferruginous chert (in percent)*

[Samples analyzed by U.S. Bureau of Mines (Harrer, 1964, p. 106)]

	1	2	3	4	5	6
Fe	32.75	38.32	32.78	35.4	29.4	25.1
Mn	5.8	1.9	4.3	3.9	1.3	3.6
Insol	36.0	35.2	39.6	35.0	51.2	49.0
TiO_2				.2	.2	.3
P				.3	.22	.26
S				.13	.09	.25

1. Sample width, 10 feet; in 100-foot adit, St. Johns mine.
2. Sample width, 10 feet; in the inclined shaft, St. Johns mine.
3. Sample width, 20 feet; from canyon south of St. Johns mine.
4–6. Character sample from St. Johns mine.

UPPER UNIT

ANDESITIC TUFFACEOUS ROCKS

The andesitic tuffaceous rocks of the upper unit of the Spud Mountain Volcanics crop out in a belt split by intrusive quartz porphyry (pl. 1, 1,216,100 N., 411,500 E.). The southern end of this belt is covered by the Tertiary Hickey Formation. A second belt of andesitic tuffaceous rocks is interbedded with the sedimentary rocks 1 mile east of Cleator.

The andesitic tuffaceous rocks exposed in the northern belt are similar to the beds of this unit exposed to the north in the NW¼ Mayer quadrangle in that they are well foliated with relict bedding preserved on many favorable exposures, particularly in the water-worn surfaces of the major gulches. These rocks are dark grayish green and contain abundant chlorite associated with some sericite and quartz.

The andesitic tuffaceous rocks in the belt east of Cleator are dark gray to black and are somewhat massive, having only limited foliation. Biotite is the dominant mafic mineral; it occurs as flakes 0.1 to 0.22 mm in diameter, more or less random arrangement, and is associated with microgranular quartz and epidote. Other rock samples having this mineralogy also contain greenish-blue amphibole needles in random arrangement. Some samples consist of subparallel bluish-green to yellow amphibole crystals separated by microgranular quartz and subordinate alkalic feldspar containing abundant epidote and sphene granules; a relict diabasic texture is suggested in the hand specimen, but thin sections do not reveal this texture. The biotite and hornblende probably are present because of the higher grade of the metamorphism in this more southerly part of the Spud Mountain Volcanics, and there is a possibility that this dark belt does contain some mafic flows in which the relict structures have been destroyed.

SEDIMENTARY ROCKS

In the Cordes area, the upper unit of the Spud Mountain Volcanics is dominated by light- to medium-gray sandy, silty, and shaly beds (pl. 1) that separate the older andesitic tuffaceous beds from the younger Iron King Volcanics to the west. These sedimentary beds are the southern extension of similar-appearing rocks interbedded with the andesitic tuffaceous rocks exposed in the NW$\frac{1}{4}$ Mayer quadrangle (Anderson and Blacet, 1972a). In the Cordes area these rocks have a much greater thickness and contain little recognizable volcanic debris. The ratio of quartz to feldspar is much higher, and siltstone is more abundant. Numerous clasts of light-colored chert are conspicuous locally.

In the northern exposures shown on the geologic map (pl. 1), these sedimentary rocks are foliated with sericite and chlorite concentrated in the planes of foliation. The feldspar clasts in the sandy beds are albitic and clinozoisite granules are numerous in the fine-grained matrix of quartz and alkalic feldspar. In the silty shale beds, feldspar is absent and clinozoisite is rare. Light-gray chert interbeds crop out in the upper part of the sedimentary sequence below the Iron King Volcanics (pl. 1). The chert consists of microgranular quartz containing varying amounts of sericite, chlorite, and minute black opaque grains (hematite?). These gray cherts contrast sharply with the ferruginous cherts interbedded with the volcanic rocks of the lower unit of the Spud Mountain Volcanics.

In the vicinity and south of coordinate 1,210,000 N. (pl. 1), the sedimentary rocks have reached a higher grade of metamorphism and the feldspar clasts are largely oligoclase, commonly containing sericite or clinozoisite inclusions. Biotite is present in varying amounts, in part parallel to foliation; locally large crystals of biotite are at an angle to foliation and commonly have a sieve structure with quartz inclusions. Chlorite is also present in varying amounts, in part appearing as chlorite-rich streaks and in part replacing biotite. Clinozoisite and epidote granules are common, particularly where biotite and chlorite are abundant. Apatite prisms and octahedra of magnetite are conspicuous as accessory minerals; sphene, garnet, and blue tourmaline are present in small amounts in some samples and are absent in others. Impure cherty beds are suggested by a high content of microgranular quartz with or without sericite, chlorite, biotite, and epidote.

Excellent exposures in Turkey Creek, south of the Jubilee mine (pl. 1, 1,205,500 N., 400,000 E.), reveal small garnet crystals in many outcrops, and studies in thin section show relict clastic textures particularly in the sandy facies. Oligoclase forms angular clasts in some beds, associated with quartz clasts, sericite, biotite, and magnetite octahedra in the fine-grained matrix. Chlorite is locally present but is absent in some samples. Small prisms of blue tourmaline are common. Southeastward in Turkey Creek (pl. 1, 1,201,300 N., 401,700 E.), staurolite crystals 20 by 30 mm in cross section are conspicuous in a crumpled quartz-muscovite schist in which biotite and epidote-group minerals are absent. Blue tourmaline prisms are numerous in thin section. This anomalous occurrence, in an outcrop nearly 1 mile north of the main zone of staurolite-bearing schist, may be related to an adjacent quartz vein.

Downstream in Turkey Creek (pl. 1, 1,199,500 N., 403,000 E. to 1,198,500 N., 405,500 E.), quartz is the dominant mineral in the rocks but oligoclase is present in variable amounts. Epidote granules are abundant, particularly in the quartz-rich parts of the rocks. Biotite and muscovite are erratic in distribution, and locally greenish-blue amphibole crystals form rosettes as well as conform to the foliation. Conversely, at this same latitute at the eastward margin of the rock sequence, epidote is absent in the quartz-rich sediments and biotite is conspicuous.

The grade of metamorphism increases southward toward the pluton of Crazy Basin Quartz Monzonite (pl. 1), and medium-grained quartz-muscovite-biotite schist forms a border about 1 mile wide that wraps around the margin of the pluton. Relict bedding and minor folds are locally preserved, but in general, detailed sedimentary structures have been erased. Garnet is widespread in the quartz-mica schist, and oligoclase and andesine occur in small amounts. K-feldspar was recognized in one sample. Locally, staurolite forms conspicuous porphyroblasts containing quartz and sericite inclusions. Epidote granules are present in some of the fine-grained and more massive quartz-mica rock. Blue tourmaline and apatite are minor accessories. Retrograde metamorphism is indicated by patches of sericitized feldspar; the chlorite replaces biotite and chlorite veinlets and selvages in some of the garnet.

The foliation planes in the northern exposures of this sedimentary sequence strike approximately parallel to the bedding, east of north, but planes near the pluton are parallel to its margin (pl. 1), indicating deformation related to forceful intrusion that caused appreciable expansion of outcrop area of sedimentary rocks to the north. Minor folds are erratic in strike and plunge, reflecting the jamming of the sedimentary rocks accompanying the forceful northward emplacement of the pluton.

Where relict textures and structures are preserved, poor sorting is characteristic of the sandy beds, but some bedding is graded. Slump structures are common in some of the finer textured beds, particularly if they are somewhat cherty in character; this suggests transport by turbidity currents. It is difficult to estimate how much of the clastic debris was of volcanic origin, but the conspicuous epidote and clinozoisite granules and chlorite flakes indicate that mafic volcanic material was present. The

TABLE 3.—*Chemical analyses of sedimentary rocks in upper unit of the Spud Mountain Volcanics*

[Rapid rock analyses by Paul Elmore, Lowell Artis, G. W. Chloe, J. L. Glenn, James Kelsey, and Hezekiah Smith]

	1	2	3	4	5	6	7	8
SiO_2	68.5	66.7	64.1	58.9	57.4	68.2	62.3	61.3
Al_2O_3	13.2	15.1	16.7	17.6	16.7	16.4	18.0	18.5
Fe_2O_3	4.3	2.5	2.8	3.4	3.5	1.1	2.3	3.0
FeO	1.6	2.0	3.8	4.9	4.5	2.7	4.8	4.0
MgO	1.6	1.1	2.4	2.4	3.4	2.8	2.1	2.3
CaO	1.8	2.6	.68	3.1	5.5	.95	1.5	2.2
Na_2O	2.7	4.0	1.4	4.9	3.0	1.6	1.9	2.0
K_2O	2.0	1.5	3.3	1.4	1.1	2.3	2.8	3.7
H_2O-	.26	.06	.19	.05	.09	.12	.08	.07
H_2O+	1.7	1.5	3.1	1.5	2.1	2.9	2.6	1.7
TiO_2	.74	.52	.70	.88	.76	.60	.60	.65
P_2O_5	.15	.11	.24	.25	.21	.18	.11	.14
MnO	.04	.07	.06	.12	.12	.07	.05	.07
CO_2	1.1	2.00	.24	.50	1.6	.05	.15	.05
Sum		100	100	100	100	100	99	100

1. Sandy tuff in NW¼ Mayer quadrangle, 1,243,000 N., 411,100 E.
2. Sandy tuffaceous rock, 1,217,500 N., 411,100 E.
3. Silty tuffaceous rock, 1,212,200 N., 410,250 E.
4. Sandy rock with chert clasts, 1,209,900 N., 408,750 E.
5. Massive sandstone, 1,209,850 N., 407,700 E.
6. Silty bedded rock, 1,205,700 N., 400,100 E.
7. Chlorite-biotite schist, 1,195,300 N., 408,600 E.
8. Biotite-muscovite schist, 1,184,000 N., 403,750 E.

high ratio of quartz to feldspar in many of the clastic beds suggests that some chemical weathering at the source area increased the quartz content and destroyed much of the feldspar that would provide clay-rich fractions for the shale (now slaty beds). Presumably rhyolitic and mafic volcanic rocks were important source material, and older granophyric rocks may have provided some of the detrital quartz on weathering, as suggested by the occurrence of granophyre pebbles in the lenticular mass of pebble conglomerate exposed in the NW¼ Mayer quadrangle (Anderson and Blacet, 1972a). It is obvious that this assemblage of bedded sedimentary rocks is not entirely volcaniclastic and that weathering of source rocks was important in the cycle of erosion and deposition. The chemical analyses of eight samples in table 3 show appreciable variation in the content of the major constituents and the lack of a clear-cut volcanic parentage.

QUARTZ PORPHYRY

The larger masses of quartz porphyry are limited to the Spud Mountain Volcanics within and to the west of the Shylock fault zone (pl. 1). Small dikelike outcrops of quartz porphyry in the eastern part of the Shylock fault zone are probably fault slivers, judging by their association with slices of gabbro, granodiorite, and various facies of Spud Mountain Volcanics (pl. 1).

The large elongate masses of quartz porphyry within the Shylock fault zone are highly foliated locally, particularly along their margins. The limitation of these larger masses to the Shylock fault zone might imply some contemporaneity of their intrusion with the formation of the fault zone, but the regional picture indicates that the Shylock fault zone is younger than the plutonic rocks emplaced after the deformation of the Yavapai Series (Anderson, 1967), and no evidence is available to suggest that any quartz porphyry was intruded after the major period of plutonism.

The rocks designated as quartz porphyry contain conspicuous quartz phenocrysts, in general ranging from 1 to 5 mm in diameter, that may or may not be associated with albitic phenocrysts 1 to 2.5 mm in length. Examination in thin section reveals that the albitic phenocrysts are clouded with sericite.

The groundmass of the quartz porphyry is microgranular quartz and alkalic feldspar ranging from 0.01 to 0.06 mm in grain size. Staining of thin sections reveals that K-feldspar is rare and that albitic plagioclase is the dominant feldspar. Sericite is conspicuous in the groundmass, particularly where the rocks are foliated. Biotite, locally partly altered to chlorite, is present in small amounts. Calcite, apatite, and blue tourmaline are common accessories. Clinozoisite and epidote are rare.

White quartz porphyry 1 mile southeast of Cordes, on the east side of Antelope Creek, is massive without a trace of foliation. Quartz and albitic plagioclase phenocrysts average about 1 mm in dimension and are embedded in a microgranular groundmass of quartz and alkalic feldspar. The feldspar is clouded with sericite and sparse clinozoisite. This outcrop may have no genetic relation to the other outcrops of quartz porphyry in this area, but there is no evidence pointing to other possible genetic relations.

Clasts of quartz porphyry are locally present in bedded tuffs and breccias of the Spud Mountain Volcanics, indicating contemporaneity of quartz porphyry intrusion with the accumulation of the volcanic rocks. The quartz porphyry is inferred to represent shallow intrusives or protrusive rhyolitic domes during the volcanic cycles, and it is included with the Spud Mountain Volcanics (pl. 1).

Two and a half miles northeast of Cleator (pl. 1, 1,202,000 N., 412,000 E.), the quartz porphyry is so intimately mixed with Spud Mountain rhyolite that the two rocks cannot be differentiated on the geologic map (pl. 1).

IRON KING VOLCANICS

Regionally, the Iron King Volcanics is folded into a major overturned syncline and only the eastern limb is exposed in the Cordes area, where it has an outcrop width of about 10,000 feet (pl. 1). The lower part of the section consists of amygdaloidal mafic flows containing many inclusions of chert and limestone; it is separated from the younger amygdaloidal flows by a wedge of ferruginous chert. Rhyolitic rocks locally intertongue with the younger mafic flows (pl. 1).

ANDESITIC AND BASALTIC FLOWS

The andesitic and basaltic flows (pl. 1) contain conspicuous amygdaloids, consisting predominantly of quartz. Their concentration at the northwestern margins of many flows indicates that the tops of the flows face northwest, confirming the synclinal structure. Pillow structures are common in the mafic flows of the Iron King Volcanics to the west and north, but they are rare and poorly developed in the Cordes area.

Foliation is locally intense and is marked by abundant chlorite in the planes of foliation, but the lavas exposed northwest of the ferruginous chert beds are generally massive, and amphibole is the dominant mafic mineral. Thin sections reveal that interlocking greenish-blue amphibole crystals have destroyed all traces of the original texture; colorless interstitial oligoclase or andesine is associated with variable amounts of quartz. Clinozoisite and magnetite and (or) ilmenite granules are disseminated through the matrix. Thin beds of chert, limestone, and tuffaceous sediments separate many of the flows.

The mafic lava flows in the lower part of the Iron King Volcanics (pl. 1) contain many inclusions of chert and limestone as well as many interbeds of chert, limestone, and breccia beds containing clasts of these sedimentary rocks and of the associated lava flows. In these lower flows, inclusions are concentrated at the base and the top, suggesting that they were produced by the flows plowing through congealed siliceous and calcareous muds. Reworking of some of this material from the tops of the lava flows produced the bedded breccias separating flows. Some flows in the lower section resemble the amphibolites northwest of the ferruginous cherts, but many contain abundant light-brown biotite crystals at places associated with greenish-blue amphibole. Chlorite is common where the rocks are strongly foliated and some of the larger associated biotite crystals cut across the foliation, indicating growth after shearing. Feldspar is difficult to distinguish from quartz in many thin sections of lava that contains numerous inclusions. Epidote, clinozoisite, and black opaque granules are common.

Chemical analyses available are sufficient to indicate that Iron King mafic flows in the area to the north range in composition from basalt to basaltic andesite (Anderson and Blacet, 1972a); an analysis of one mafic flow in the report area indicates a basaltic composition (table 4, sample 1).

RHYOLITIC ROCKS

Rhyolitic rocks are present only northwest of the wedge of ferruginous chert (pl. 1). The outcrop exposed in and north of Cedar Creek is massive and silicified in the northern exposures and highly foliated at Cedar Creek. In the massive facies, albitic phenocrysts clouded by sericite range in length from 0.25 to 0.7 mm and form clusters; the associated quartz phenocrysts are scarce and have a diameter of 0.3 mm. The microcrystalline groundmass consists of quartz and alkalic feldspars with accessory

TABLE 4.—*Chemical analyses of lavas in the Iron King Volcanics*

[Rapid rock analyses by Paul Elmore, Lowell Artis, G. W. Chloe, J. L. Glenn, James Kelsey, and Hezekiah Smith]

	1	2	3
SiO_2	50.4	75.1	82.1
Al_2O_3	14.8	13.8	10.3
Fe_2O_3	3.0	.76	.28
FeO	7.7	1.4	.20
MgO	8.3	2.4	.17
CaO	9.1	.08	.00
Na_2O	3.2	1.6	.10
K_2O	.14	2.1	5.9
H_2O-	.05	.20	.06
H_2O+	1.1	2.2	.53
TiO_2	1.0	.14	.14
P_2O_5	.13	.04	.03
MnO	.16	.00	.00
CO_2	.05	$<.05$	$<.05$
Sum	99	100	100

1. Basaltic flow associated with lava containing chert and limestone inclusions, 1,210,200 N., 401,400 E.
2. Rhyolitic tuff 1,216,200 N., 403,000 E.
3. Rhyolitic intrusive rock, 1,215,650 N., 402,800 E.

magnetite. The rock is cut by many intersecting quartz veins. Granulated quartz phenocrysts and a few relict albitic phenocrysts are present in the foliated facies, marked by abundant sericite and granular quartz along the planes of foliation. Locally, pale-green chlorite exceeds sericite. Accessory stubby blue tourmaline prisms are minor and quartz-magnetite veins cut some of the foliated rhyolite. This mass of rhyolite may be a flow or shallow intrusive.

At the Blue Bell mine (pl. 1) rhyolitic pyroclastic rocks are exposed for a distance of 4,000 feet and are intruded by a porphyritic facies of rhyolite that to the northwest forms a narrow border about 1,500 feet long and to the southeast forms a stubbier border with narrow dike projections totaling about 3,000 feet in length.

The pyroclastic rocks contain conspicuous sericitic clasts 20 to 44 mm long but only 2 to 4 mm thick. In thin section these clasts resemble collapsed pumice-lapilli. Small clasts of lithic rhyolite are largely groundmass chips but a few contain small quartz phenocrysts. A small amount of K-feldspar is revealed by staining, but much of the feldspar is plagioclase with a low index of refraction. Chlorite and biotite are present in small amounts, possibly indicating some admixture of more mafic volcanic detritus. Locally clinozoisite granules are present as well as accessory blue tourmaline prisms. The pyroclastic rocks are foliated, with dominant sericite concentrated in the foliation planes. A chemical analysis (table 4, sample 2) indicates the rhyolitic character marked by a low content of total Na_2O and K_2O.

The intrusive porphyritic facies near the Blue Bell mine contains quartz phenocrysts ranging from 0.5 to 1.5 mm in diameter embedded in sericite-rich microgranular groundmass of quartz; K-feldspar is revealed by staining in the southeastern mass, and a chemical analysis (table 4, sample 3) reveals 5.9 percent K_2O. The parallel streaks of sericite define the strong foliation of this facies. In the northwestern mass, pyrite granules are associated with sericite in the foliation planes.

FERRUGINOUS CHERT

The ferruginous chert is well exposed in Cedar Creek (pl. 1), where it has an outcrop width of more than 2,000 feet, but it thins to the southwest and has a width of about 400 feet east of the Blue Bell mine. At about 2,000 feet from the southern termius, the iron-bearing minerals disappear and the chert is light colored.

In Cedar Creek, the chert beds contain magnetite-rich layers from 1 to 5 mm wide, and numerous folds of small amplitude are well exposed. The section contains many interbeds of tuffaceous material similar to the material separating many of the mafic flows. How much thickening of section is caused by internal folding is debatable, as many of the minor folds have steep to vertical plunges. Garnet and brown mica are common in the metamorphosed sediments, and tremolite is locally associated with garnet. The iron oxide layers in the Cedar Creek section strongly attract a magnet. Examination of polished surfaces reveals that these layers consist largely of magnetite, with only narrow hematite margins and intergrowths, whereas south of Cedar Creek, the layers contain more hematite than magnetite.

Locally, knobs of dark quartz-rich lenses, pods, and veins without a trace of bedding stand out above the bedded cherts (pl. 1). Presumably, these represent recrystallized chert beds, as magnetite and hematite are present in minute grains, but the outcrops are crisscrossed by white quartz veins. (See also "Quartz Lenses and Veins," p. 26.)

The U.S. Bureau of Mines sampled the ferruginous chert beds to the southeast of the Blue Bell mine (Harrer, 1964, p. 103); analysis of a character sample gave the following results: SiO_2, 52.4 percent; Fe, 29.0 percent; Mn, 0.9 percent; TiO_2, 0.6 percent; and S, 0.11 percent. Spectrographic analyses revealed that the Co, Cu, and Ni content ranged from 0.0 to 0.1 percent and V and Zr from 0.001 to 0.01 percent.

Ferruginous chert crops out in several narrow bands in the younger mafic flows west of the large mass of chert (pl. 1).

INTRUSIVE ROCKS

The intrusive rocks of Precambrian age are largely limited to the southeastern quadrant of the Cordes area, except for the pluton of Crazy Basin Quartz Monzonite in the southwestern quadrant (pl. 1). These Precambrian intrusive rocks range from early quartz diorite porphyry to late quartz monzonite and granodiorite porphyry in composition; they are predominantly granodiorite, with small amounts of associated diorite and gabbro.

QUARTZ DIORITE PORPHYRY

The quartz diorite porphyry is well exposed along and south of Big Bug Creek along the eastern margin of the area (pl. 1), where the porphyry clearly intrudes the Spud Mountain Volcanics and is, in turn, intruded by the Badger Spring Granodiorite. Quartz diorite porphyry crops out less than 1 mile southeast of Cordes along the main road. Smaller outcrops occur to the south, where the porphyry intrudes Spud Mountain andesite and is in turn intruded by the Bumblebee Granodiorite.

The dominant phenocrysts are white plagioclase, 1 to 2.5 mm long, associated with smaller, subordinate quartz phenocrysts, embedded in a fine crystalline groundmass. Examination in thin section reveals that the plagioclase is altered with inclusions of clinozoisite or epidote granules or sericitic flakes in an albitic base. Original biotite phenocrysts averaging about 1 mm in size have been altered to chlorite. The groundmass is fine to microgranular, consisting of quartz and alkalic feldspar, with K-feldspar occurring in only a small percentage of samples examined. Locally, the porphyry is foliated and the quartz phenocrysts are granulated, forming subparallel streaks. A chemical analysis (table 5, sample 5) substantiates the classification of quartz diorite porphyry.

GABBRO

The large masses of gabbro are spatially associated with the Badger Spring Granodiorite, south of Cordes (pl. 1), where they form roof pendants in, or are marginal to, the younger granodiorite. Several fault slivers of gabbro are exposed in the eastern part of the Shylock fault zone. Small isolated masses of gabbro intrude the Spud Mountain Volcanics shown in the northern part of plate 1. The fault slivers in the Shylock fault zone are highly foliated, particularly at their margins, but elsewhere the gabbro is generally dark and granular with a variable grain size; the small masses tend to be fine grained and the large masses, medium grained.

The dominant minerals are brilliant black hornblende and dull saussuritized plagioclase. Studies in thin section reveal that the hornblende is largely euhedral, pleochroic in shades of brown and brownish green, and that locally it poikilitically encloses small crystals of plagioclase. The plagioclase is predominantly euhedral, containing abundant granules of clinozoisite and epidote in an albitic base. Quartz is commonly interstitial to the hornblende and plagioclase, locally showing a poikilitic texture, but in general quartz is present only in minor quantities. In some samples the hornblende is partly altered to chlorite with thin tremolite borders. Leucoxene granules are conspicuous. Apatite and magnetite are common accessories.

The distinction between "gabbro" and "diorite" is difficult to make for these mafic masses in the Cordes area. Hornblende is common in many rocks termed "diorite," but the abundant clinozoisite indicates that the original plagioclase had a high content in anorthite, a characteristic feature of most gabbro. Interstitial quartz is common in both diorite and gabbro. For descriptive purposes of this report, these dark granular rocks are termed "gabbro;" other geologists may prefer "diorite." The chemical analysis (table 5, sample 1) of a sample from one of the larger masses is more indicative of diorite.

BUMBLEBEE GRANODIORITE

The Bumblebee Granodiorite is limited to the southeastern margin of the area (pl. 1), where it forms bold and rounded outcrops along and east of Bumblebee Creek. The western margin of this granodiorite is a dark rock rich in hornblende that is distinguished as a mafic border facies on plate 1. This facies grades eastward into the dominant lighter rock in which hornblende and biotite are less prominent.

The Bumblebee Granodiorite intrudes the Spud Mountain Volcanics and the quartz diorite porphyry and in turn is intruded by the Badger Spring Granodiorite. In the southeastern corner of the area (pl. 1), the Bumblebee Granodiorite is partly covered by the Tertiary Hickey Formation.

The Bumblebee Granodiorite is characterized by abundant saussuritized plagioclase, which may account for the difficulty in breaking suitable hand specimens from the fresh exposures. Examination in thin section reveals that the texture is seriate. The larger hornblende crystals are 4 mm long but average about 2 mm. The plagioclase ranges in length from 0.2 to 3 mm. Quartz ranges from 0.5 to 2 mm in diameter and is largely interstitial to the plagioclase, hornblende, and chloritized biotite. K-feldspar in small amounts interstitial to the quartz and plagioclase is revealed by staining, but it is absent in the mafic border facies.

The plagioclase is clouded with abundant clinozoisite granules and scattered sericite flakes in an albitic base. The hornblende is pleochroic in shades of green and brown, whereas the original biotite is altered to chlorite and epidote. Along Bumblebee Creek, samples of the unweathered granodiorite contain only chloritized hornblende. Sphene, apatite, zircon, and magnetite are common minor accessories.

Chemical analysis of the marginal facies of the Bumblebee Granodiorite is given in table 5 (sample 2), and an analysis of a representative sample of the main part of the mass is given in table 5 (sample 3). The marginal facies approaches a quartz diorite in composition, whereas the interior facies is a typical granodiorite (fig. 2).

Greenish dikes, ranging in width from several feet to 20 feet, are common in the Bumblebee Granodiorite; most of these trend N. 30° W. to N. 45° W., but other dikes trend more westerly, northeast, and east. The dikes have a relict diabasic texture with the plagioclase converted to albite and clinozoisite granules, separated by interstitial quartz, chlorite, and light-green amphibole.

BADGER SPRING GRANODIORITE

The coarse-grained Badger Spring Granodiorite is the dominant granitic rock exposed south of Cordes (pl. 1), where it clearly intrudes the Spud Mountain Volcanics, gabbro, and quartz diorite porphyry and is covered in part by the sedimentary rocks of the Hickey Formation. There is a small exposure in Big Bug Creek, at the eastern margin of the area mapped (pl. 1), where the Badger Spring Granodiorite intrudes the mafic border facies of the Bumblebee Granodiorite. Northeast of Cordes a porphyritic facies forms small plugs or narrow dikes intrusive into Spud Mountain Volcanics, and less than 2 miles east of Cordes, two dikes of the porphyritic facies intrude the Bumblebee Granodiorite. This coarse-grained granodiorite is well exposed in Badger Spring Wash, the type locality, east of the Cordes area in the SE¼ Mayer quadrangle.

The characteristic feature of the Badger Spring Granodiorite is the abundance of rounded quartz grains ranging from 3 to 12 mm in diameter and averaging, in general, about 8 mm. These grains are associated with abundant opaque white saussuritized plagioclase crystals, commonly as large as the quartz grains. Biotite is the dominant mafic mineral; it largely forms scattered shredded-looking aggregates separating the quartz and plagioclase. This granodiorite weathers to tan-colored, rounded outcrops that are deeply weathered to crumbly aggregates except in the deeper stream canyons.

Along the eastern margin of the Shylock fault zone, the Badger Spring Granodiorite is foliated and crushed; locally it forms zones 15 to 20 feet wide of schistose rock in which the coarse quartz grains are ground to elongate lenses.

Thin-section studies reveal that the texture is essentially seriate, with much quartz and plagioclase about 1 to 3 mm in size separating the larger crystals. Quartz is generally strained but is only granulate near the Shylock fault zone. The plagioclase is heavily clouded with clinozoisite granules and randomly oriented sericite flakes but has clear albitic borders. K-feldspar is absent in many specimens, but where present it generally forms aggregates interstitial to the plagioclase and quartz. A sample from Big Bug Creek contains K-feldspar with perthitic intergrowths in crystals approaching the size of some of the associated plagioclase crystals. The biotite is largely altered to chlorite mixed with granules and prisms of epidote. Intersecting narrow rods of rutile(?) form circular to elliptical patterns in much of the chlorite. Sphene, zircon, and apatite are the common accessory minerals. Calcite rarely appears as granules.

Southwest of Cordes near the older gabbro, the Badger Spring Granodiorite is dark and locally medium grained. Micrographic intergrowths of quartz and plagioclase appear between the larger crystals.

The porphyritic facies forming plugs and dikes contains conspicuous quartz and saussuritized plagioclase phenocrysts embedded in a microcrystalline groundmass of quartz and feldspar in which K-feldspar is revealed in some samples by staining. Chlorite after biotite is present, as well as the epidote and clinozoisite so conspicuous in the coarse-grained facies. Locally, micrographic intergrowths of quartz and feldspar appear.

Cutting the Badger Spring Granodiorite are a number of narrow greenish-gray dikes similar to the diabasic-textured dikes that intrude the Bumblebee Granodiorite.

Chemical analyses of samples of the Badger Spring Granodiorite are given in table 5. Sample 6 is from the report area, and samples 4 and 7 are from similar coarse-grained Badger Spring Granodiorite along the road to Horseshoe Ranch (SE¼ Mayer quadrangle). The three analyses show a range in composition from quartz diorite to granodiorite (fig. 2), but the greater part appears to be largely granodiorite.

TABLE 5.—*Chemical analyses of Precambrian intrusive rocks*

[Rapid rock analyses by Paul Elmore, Lowell Artis, S. D. Botts, G. W. Chloe, J. W. Glenn, James Kelsey, and Hezekiah Smith]

	1	2	3	4	5	6	7
SiO_2	53.7	58.0	67.0	69.6	71.1	72.2	74.3
Al_2O_3	19.1	17.2	14.3	14.7	14.6	13.9	13.0
Fe_2O_3	2.5	1.8	1.3	.82	1.1	1.11	.97
FeO	5.6	6.2	3.6	2.8	2.0	2.2	1.3
MgO	3.2	2.9	1.7	1.1	.76	.64	.50
CaO	8.2	6.6	4.8	4.1	2.0	2.7	2.4
Na_2O	2.4	2.7	3.2	3.5	4.9	3.4	4.4
K_2O	.67	1.4	1.7	1.0	.73	2.0	1.4
H_2O-	.06	.10	.09	.11	.08	.07	.11
H_2O+	2.7	2.0	1.4	1.5	1.5	1.1	1.0
TiO_2	.74	.85	.49	.32	.33	.10	.25
P_2O_5	.11	.13	.10	.06	.09	.06	.02
MnO	.14	.16	.30	.02	.07	.06	.08
CO_2	.10	<.05	<.05	<.05	.21	.16	<.05
Sum	99	100	100	100	99	100	100
Powder density			2.74	2.75		2.68	2.65
Bulk density			2.74	2.73			2.65

1. Gabbro (diorite), SW¼ Mayer quadrangle, 1,186,650 N., 429,900 E.
2. Quartz diorite, mafic facies of Bumblebee Granodiorite, SW¼ Mayer quadrangle, 1,202,600 N., 434,300 E.
3. Bumblebee Granodiorite, SW¼ Mayer quadrangle, 1,197,000 N., 436,700 E.
4. Badger Spring Granodiorite, SE¼ Mayer quadrangle, 1,188,100 N., 444,800 E.
5. Quartz diorite porphyry, SW¼ Mayer quadrangle, 1,213,800 N., 435,650 E.
6. Badger Spring Granodiorite, SW¼ Mayer quadrangle, 1,191,700 N., 423,000 E.
7. Badger Spring Granodiorite, SE¼ Mayer quadrangle, 1,187,700 N., 450,600 E.

CRAZY BASIN QUARTZ MONZONITE

The Crazy Basin Quartz Monzonite is exposed in the southwestern corner of the Cordes area (pl. 1) and forms the northern part of a large pluton that extends southward into the Crown King and Bumblebee quadrangles. Northward, the pluton intrudes sedimentary rocks of the upper unit of the Spud Mountain Volcanics. The

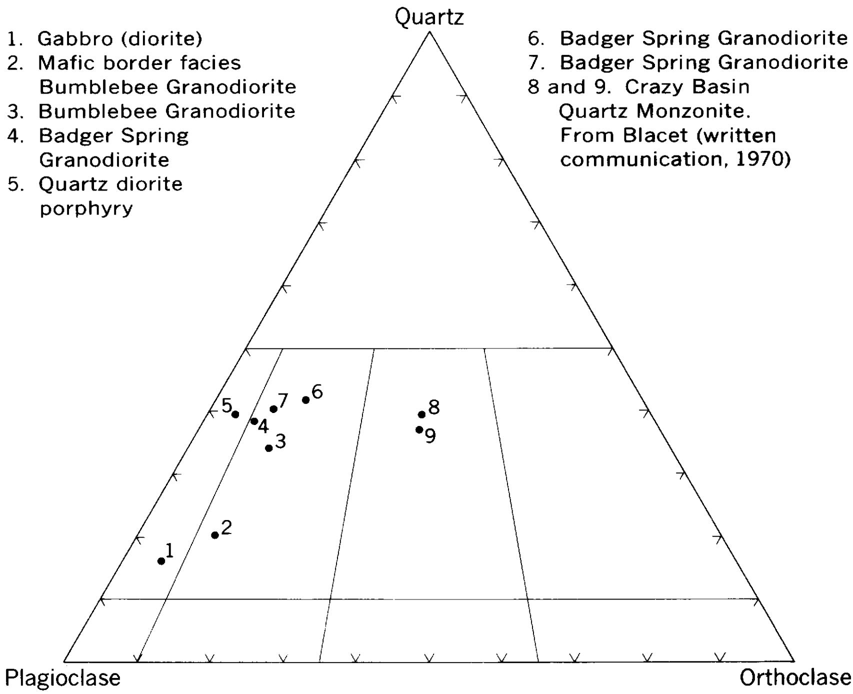

FIGURE 2.—Plots of normative quartz-orthoclase-plagioclase of the Precambrian instrusive rocks. See table 5 for analyses of samples 1–7.

type locality is Crazy Basin Creek in the Mount Union and Mayer quadrangles.

The quartz monzonite contains conspicuous K-feldspar crystals, 8 to 10 mm long, embedded in a matrix of K-feldspar, plagioclase, quartz, and biotite crystals ranging in size from 2 to 4 mm. Examination in thin section reveals that the K-feldspar is microcline, and chemical analyses (Blacet, 1968) indicate that the rock is properly classified as quartz monzonite (fig. 2).

At the northern part of the pluton (pl. 1, western margin), finer grained quartz monzonite is exposed that may represent a border facies. Quartz and K-feldspar (microcline) are present in part as 2- to 4-mm crystals as well as smaller grains associated with plagioclase (andesine) that exhibits little conspicuous twinning. A crude foliation is indicated by a subparallel arrangement of accessory biotite and muscovite crystals. Sphene, apatite, zircon, and magnetite are minor accessories.

Locally at the margin of the pluton (pl. 1, 1,190,600 N., 399,700 E.) aplite and pegmatite separate the Crazy Basin Quartz Monzonite from the Spud Mountain Volcanics. The pegmatitic facies contains K-feldspar crystals 7.5 to 10 cm long, muscovite books 2.5 to 5 cm in diameter, and black tourmaline crystals 2.5 to 5 cm long. Similar rocks form dikes in the Spud Mountain Volcanics north and east of the pluton.

GRANODIORITE PORPHYRY

Two pluglike masses of granodiorite porphyry intrude the Spud Mountain Volcanics more than 1 mile northeast of Cleator (pl. 1). As the western plug is largely disintegrated to sand-sized fragments and the outcrops are stained by limonite, fresh samples are difficult to obtain. The eastern plug is exposed in a stream canyon and is not as friable as the western plug. The eastern plug is cut by many quartz veins, and the large blebs of quartz within and north of it may be genetically related to the granodiorite porphyry.

Brilliant white plagioclase phenocrysts 6 to 8 mm long dominate the texture of the porphyry. Refractive indices of the plagioclase indicate andesine composition. Biotite books 3 to 4 mm in diameter and hornblende prisms 6 to 8 mm in length are widely scattered in the fine- to medium-grained groundmass of the western plug. Biotite books and abundant hornblende prisms 2 to 3 mm in size characterize the eastern plug. The fine- to medium-grained groundmass of the porphyry in both plugs consists of twinned plagioclase that is oligoclase to andesine in composition, quartz, and interstitial untwinned K-feldspar. Sphene, apatite, and magnetite are the minor accessories.

The lack of saussuritization of the plagioclase is in marked contrast to the various facies of granodiorite exposed to the east, and the absence of microcline is in contrast to the Crazy Basin Quartz Monzonite to the southwest of these plugs. Whether or not these plugs are genetically related to either of these plutonic rocks is debatable.

QUARTZ LENSES AND VEINS

The siliceous lenses and veins (pl. 1) include white granular quartz, reddish jasper, and dark-gray to black quartz containing disseminated hematite and (or) magnetite. The white veins and lenses are limited largely to the Badger Spring Granodiorite south of Cordes. The dark-colored quartz rocks are common in the Spud Mountain Volcanics and associated quartz porphyry in and near the Shylock fault zone (pl. 1), as well as in the Spud Mountain Volcanics 2 to 3 miles northeast of Cordes. Short, stubby, black quartz lenses are widely distributed in the Iron King Volcanics in the northwestern corner of the area (pl. 1).

Many of the dark-colored lenses and veins may be recrystallized ferruginous chert, particularly those in or closely associated with ferruginous chert beds and those which are conformable with the associated lava flows or interbedded sediments. Some of these, however, are discordant to the bedding structures or are in intrusive masses of rhyolite (pl. 1, 1,211,000 N., 434,000 E.) and must represent deposition of quartz and associated iron-bearing minerals in fracture zones.

A typical dark-gray quartz lens consists of microcrystalline quartz grains averaging about 0.1 mm in diameter cut by veinlets of much coarser grained quartz. The magnetite and (or) hematite grains are disseminated in the microcrystalline quartz or form chainlike veinlets.

A Precambrian age for these quartz lenses and veins cannot be proven, but the occurrence of many along fractures in the Shylock fault zone of Precambrian age suggests that the other pods and veins are probably of Precambrian age.

SILICIFIED AND SERICITIZED ROCKS

Silicified and sericitized rocks shown on the north-central margin of the geologic map (pl. 1) are a part of a large mass of quartz-sericite rock exposed in the eastern margin and east of the Shylock fault zone in the NW¼ Mayer quadrangle. Various units of the Spud Mountain Volcanics remain as isolated exposures within the quartz-sericite rock, indicating that the Spud Mountain Volcanics has been silicified and sericitized (Anderson and Blacet, 1972a),

The silicified and sericitized rocks form bold craggy outcrops in which no relict textures or structures can be recognized. These outcrops have a tan weathered surface, the fresh surfaces are light to medium gray. Foliation is of limited distribution and only locally are the rocks highly foliated and marked by abundant sericite. Most outcrops show tight intersecting fractures. Studies in thin section reveal that the rocks are composed largely of quartz, appearing as granular blebs, rounded aggregates, and irregular grains, averaging about 0.5 mm in diameter. The matrix is largely microcrystalline quartz and sericite, spotted by nests of chlorite. Minor amounts of sphene, leucoxene, and rutile are present in the matrix, but rarely do all three titanium minerals appear in the same sample. Chemical analyses of the massive and foliated facies are given by Anderson and Blacet (1972a).

CRETACEOUS OR TERTIARY ROCKS

RHYOLITE PORPHYRY

Dikes and plugs of rhyolite porphyry are few in the Cordes area, but are common in the Mount Union quadrangle to the northwest where they intrude a granodiorite stock of Late Cretaceous or early Tertiary age. Presumably the rhyolite porphyry dikes are of the same general age (Anderson and Blacet, 1972a).

East of Cleator, one dike can be traced northward for about 4,000 feet, and a small plug crops out about 700 feet east of the northern end of the dike. Another dike, about 1,000 feet long, is exposed about 4,000 feet southwest of Cleator. These dikes are narrow, ranging from 10 to 50 feet wide.

The rhyolite porphyry is appreciably altered, forming dull buff outcrops, but phenocrysts of quartz and feldspar can be detected locally. Thin sections reveal that the groundmass is fine granular quartz and sericitized alkalic feldspar.

CENOZOIC ROCKS

In the Cordes area the Cenozoic rocks include the Hickey Formation of Miocene and Pliocene age. The age is based on K/Ar dates of 14.6 to 10.1 m.y. determined by E. H. McKee (written commun., 1970). Younger rocks are reddish Pleistocene gravels and Quaternary terrace and river wash deposits. The Hickey Formation consists of olivine basalt flows and cinder cones with intertonguing gravel and sand, whereas the younger formations are essentially unconsolidated gravel containing interbeds of coarse sand and silt.

HICKEY FORMATION

The Hickey Formation was defined by Anderson and Creasey (1958, p. 56–59) as a sequence of basaltic flows and intertonguing basaltic sediments exposed on the summit of Mingus Mountain. At the base of the volcanic rocks in the type area, coarse gravel and sand, consisting largely of nonvolcanic debris, are exposed. Southward from Mingus Mountain, the basaltic flows diminish in volume; this decrease is accompanied by an increase in thickness of intertonguing gravel, sand, and, locally, silt and fine marl (Anderson and Blacet, 1972a). The widespread sediments and minor outcrops of basalt shown on the northeastern corner of the map (pl. 1) are in part southward extensions of the Hickey Formation from the Mingus Mountain area.

The basaltic flows and associated sediments exposed in the northwest corner of the Cordes area appear to be related to similar olivine basalts with minor amounts of gravel and sand that cover Big Bug Mesa in the NE¼ Mount Union quadrangle. However, dikes and cinder cones indicate local sources for some of the basaltic flows in the Cordes area. Intertonguing gravel and sand increases in thickness southward from Big Bug Mesa (Anderson and Blacet, 1972a), and southeast of Cordes the sedimentary facies of the Hickey Formation is dominant.

In the Cordes area, a relief of at least 500 feet is indicated prior to the outpouring of the lavas and deposition of the associated sediments, judging from the exposures in the west-central margin of the Hickey Formation (pl. 2, section *B–B′*). An isolated remnant of a dense olivine basalt flow remains on a ridge less than 1 mile northwest of Cleator, and the base of this flow is essentially parallel to the slope of the ridge, suggesting that the pre-Hickey erosional surface at this place probably sloped southeastward at about the same grade as the present ridge and that the relief in pre-Hickey time may have resembled the present relief. Elsewhere the relief may have been more moderate.

White latite is exposed beneath the olivine basalt flows in six small areas (pl. 1, 1,217,000 to 1,220,000 N.; 416,000 to 418,500 E.). The center of eruptive activity is an elliptical dome with steep flow banding; the chemical analysis of a sample from this dome proves the latitic character (table 6, sample 4). The other exposures are of a compact and massive tuff and breccia composed of latite clasts cemented in part by calcite. Brilliant black hornblende phenocrysts that characterize the latite are revealed in thin section as reddish-brown crystals embedded in a microcrystalline trachytic groundmass of K-feldspar and plagioclase. The latite is included with the Hickey Formation, but radiometric dating may prove that it is an erosional remnant of an older sequence.

The individual basaltic flows range in thickness from 20 to 50 feet where they can be distinguished on cliff exposures. Locally, some of the brecciated tops of the individual flows are cemented by calcite. A partly exhumed cinder cone cut by many basaltic dikes 5 to 10 feet wide is revealed at Dripping Spring. The reddish to orange cinders include vesicular blocks of basaltic lava up to 2 feet long, and many bombs are 2 to 3 feet long.

Olivine, generally altered in part to reddish iddingsite, is a conspicuous mineral in all of the basaltic flows. Thin sections

TABLE 6.—*Chemical analyses of volcanic rocks in the Hickey Formation*

[Rapid rock analyses by Paul Elmore. Lowell Artis, S. D. Botts, G. W. Chloe, J. L. Glenn, Hezekiah Smith, D. Taylor]

	1	2	3	4
SiO_2	45.7	48.8	50.8	59.9
Al_2O_3	13.9	15.1	16.7	17.3
Fe_2O_3	5.5	4.1	2.9	5.4
FeO	6.0	5.8	5.4	.20
MgO	9.0	8.0	6.4	2.3
CaO	10.7	9.6	7.3	4.2
Na_2O	2.9	3.0	4.0	5.8
K_2O	1.0	1.2	1.6	3.2
H_2O-	.57	.63	.61	.41
H_2O+	1.6	1.8	2.0	.39
TiO_2	2.1	1.8	1.7	.66
P_2O_5	.75	.70	.62	.59
MnO	.21	.20	.20	.14
CO_2	.04	.04	.06	$<.05$
Sum	100	101	100	100

1. Olivine basalt, 1,202,700 N., 418,550 E.
2. Olivine basalt, 1,223,450 N., 422,000 E.
3. Olivine basalt, 1,199,800 N., 424,300 E.
4. Latite, 1,219,000 N., 416,600 E.

reveal that the olivine is embedded in an intergranular groundmass of pale–gray augite, zoned plagioclase, and black opaque grains. Chemical analyses of three samples of basalt (table 6) show a range in SiO_2 content of 45.7 to 50.8 percent and a range in K_2O content of 1.0 to 1.6 percent, indicating that the basalts are alkalic.

In general, outcrops of the gravels and sands of the Hickey Formation are limited to favorable cliff exposures. In the areas of low relief, numerous cobbles and boulders are concentrated on the present erosion surface, and these are predominantly rock types resistant to weathering and erosion such as quartz, quartz-tourmaline, quartz-rich mica schists, chert, leucocratic fine-grained granitic rocks, pegmatites, and dense greenish dike rocks. Where these strata are the base of the Hickey Formation, basaltic debris is absent, but in gravels and sands intercalated with basaltic flows, local layers of bedded volcanic detritus are present. In areas where the Precambrian rocks apparently cropped out in hills that were buried by the Hickey Formation, angular clasts of these rocks may be common in the sediments. For example, quartz porphyry and Spud Mountain andesitic clasts are abundant about 1 mile west of Dripping Spring (pl. 1, 1.203,200 N. 410,000 E.). In the thick section exposed west of Bumblebee Creek in the southeastern corner of the area, clasts of quartz diorite porphyry, diorite, and Bumblebee Granodiorite are present.

The quartz-rich mica schist and pegmatitic rocks are not exposed north of the report area, and their occurrence in the sediments, particularly in the western part of the area shown on the map (pl. 1) suggests a source to the west or south where these basement rocks are well exposed.

The sediments exposed in the northeastern corner of the area (pl. 1) contain many clasts of olivine basalt associated with clasts of various types of silicified rock and quartz, cherty iron-formation, Spud Mountain breccia, and mica schist. Some of this detritus could have a northwestern source, but the presence of the mica schist suggests that some detritus came from the southwest. A more exhaustive study of the clasts throughout the region is required to establish the direction of the many stream currents that supplied the debris to the Hickey sediments.

REDDISH GRAVELS

Reddish gravels that are largely a heterogeneous accumulation of boulders, cobbles, pebbles, and fine-grained sediment, all of local derivation, form deposits ranging in thickness from a foot to more than 30 feet. These gravels are generally stained by reddish iron oxide, particularly at the surface. In part they develop on bedrock, but in the report area, the gravels are largely developed on the Hickey Formation and they represent reworking of the gravel in that formation in the tributaries to the larger streams.

Gravel veneers on pediment surfaces are common in the Mingus Mountain and Prescott quadrangles (Anderson and Creasey, 1958, p. 61; Krieger, 1965, p. 85–86). Similar gravels, in part forming only small patches, are present in the NE¼ Mount Union quadrangle and NW¼ Mayer quadrangle (Anderson and Blacet, 1972a).

TERRACE DEPOSITS AND RIVER WASH

Terrace deposits are limited to Big Bug Creek in the northeastern part of the Cordes area, to Antelope Creek southeast of Cordes, and to Turkey Creek in the southwestern part of the area (pl. 1). These terrace deposits range in thickness from 10 to 20 feet and consist of alternating layers of fine, medium, and coarse sand, scarce gravel lenses, and a few silty beds.

Deposits of river-wash sand are limited to the lower parts of Government Spring Wash and Bumblebee Creek (pl. 1) and their tributaries where the granodiorite plutons weather rapidly to sand.

STRUCTURE OF THE PRECAMBRIAN ROCKS

SHYLOCK FAULT ZONE

The Shylock fault zone, a major structural feature in this region, is at least 45 miles long. The cover of unbroken Cambrian Tapeats Sandstone in the Mingus Mountain quadrangle proves the Precambrian age of the faulting. The fault zone is approximately 1 mile wide and a minimum of 5 miles right-lateral slip is indicated by offset slices of quartz diorite in the Mingus Mountain quadrangle (Anderson, 1967). The Texas Gulch Formation, a Precambrian sedimentary unit that is younger than the Yavapai Series and some of the plutons, forms large fault slices in the Shylock fault zone in the NW¼ Mayer and Mingus Mountain quadrangles. These fault slices are associated with Spud Mountain Volcanics and quartz porphyry.

The Shylock fault zone extends southward 15 miles into the Bumblebee quadrangle, where it was mapped and named the "Black Canyon fault zone" by Jerome (1956). His map shows beautifully how some of the individual units in the sedimentary and volcanic rocks are truncated by the western margin of the fault zone.

In the Cordes area, Spud Mountain Volcanics and quartz porphyry make up most of the fault slices in the Shylock fault zone, but locally in the southern end of the zone, slices of gabbro and Badger Spring Granodiorite are present (pl. 1). The eastern margin of the fault zone is characterized by mylonitized Badger Spring Granodiorite and Spud Mountain rhyolite; the western margin is less definite. The highly foliated rocks in the fault zone contain appreciable chlorite and sericite, suggesting some retrogressive metamorphism during the faulting as the adjacent metamorphic rocks are of higher grade, particularly in the southwestern corner of the area. The time interval between the intrusion of the plutonic rocks and formation of the Shylock fault zone is unknown.

The Shylock fault zone in the Cordes area separates the Precambrian rocks into two structural blocks. In the western block, the Spud Mountain and Iron King Volcanics represent the eastern limb of a major syncline, modified in part by the pluton of Crazy Basin Quartz Monzonite. East of the fault zone much of the Spud Mountain Volcanics is covered by the Tertiary

Hickey Formation or engulfed by the plutons of the Badger Spring and Bumblebee Granodiorites.

WEST OF THE SHYLOCK FAULT ZONE

In the northern part of the Cordes area, the Spud Mountain and Iron King Volcanics dip steeply to the west in normal stratigraphic succession. Cleavage-bedding intersections and minor fold axes in the Spud Mountain Volcanics plunge steeply southward. In the southwestern part of the area, the Spud Mountain Volcanics has been split by the pluton of Crazy Basin Quartz Monzonite; the greater part of this separation is exposed in the SE¼ Mount Union quadrangle (Blacet, 1968). A northward jamming of the Spud Mountain sedimentary rocks is indicated by their increased outcrop width, the northward plunge of many minor fold axes, and the wraparound of bedding and foliation parallel to the northern margin of the pluton. The small outcrop of Iron King Volcanics (pl. 2, section *B–B′*) is the end of a northeast-trending syncline; the trough of the syncline consists of mafic flows in the lower unit of the Iron King Volcanics. This fold is discordant to the major synclinal axis (N. ± 20° E.) exposed to the west in the SE¼ Mount Union quadrangle and must be related in origin to the deformation produced by the pluton (Blacet, 1968).

EAST OF THE SHYLOCK FAULT ZONE

Only limited information is available on the structure of the Spud Mountain Volcanics east of the Shylock fault zone, owing in part to the probability that much of the Spud Mountain rhyolite is intrusive and its contacts with the other units of the Spud Mountain Volcanics are not revealing as to the structure. Near the eastern margin of the area (pl. 1, 1,205,000 N. to 1,209,000 N.), contacts between the basaltic flows and andesitic breccia indicate N. 20° E. trends, whereas to the northwest (pl. 1, 1,214,400 N., 431,200 E.) limited northwest-trending bedding is exposed. The dominance of northerly trends suggests that the major folds may have this trend.

ORE DEPOSITS

Mining activity in the northern Bradshaw Mountains began in 1863 with the discovery of gold placers south and southeast of Prescott. Lode mining in the general region began about 1875, when silver and gold deposits were located. In the Cordes area, significant production has been reported only from the Blue Bell mine. The initial discovery of this deposit was probably made in the late 1870's, but as there were no rich surface ores, no mining was done until 1896. Early in the 20th century, a smelter was built at Humboldt, 12 miles due north, to treat ore from the Blue Bell mine, and by 1906, the mine was a major copper producer (Dunning, 1959, p. 349).

From 1896 to 1926, the Blue Bell mine operated intermittently, owing to changes in smelter ownership and instability of the copper market (Dunning, 1959, p. 350). During that period, 33,500 tons of copper was produced and in addition gold valued at $1 million and silver valued at $1.2 million, representing a total value of $14 million (Elsing and Heineman, 1936, p. 101), was produced. During the period 1944–48, L. L. Farnham mined oxidized copper ore from the top of one of the major ore shoots adjacent to the main shaft. More than 7,000 tons of ore was produced, averaging about 5 percent copper, largely in the form of cuprite and native copper, valued at about $150,000 (Dunning, 1959, p. 350; L. L. Farnham, written commun., May 25, 1965). The mine has been idle since 1948.

The Blue Bell ore body is one of several Precambrian massive sulfide deposits in the Yavapai Series in this general region; these deposits include the United Verde and United Verde Extension at Jerome, the Iron King at Humboldt, and several smaller deposits in the NW¼ Mayer quadrangle—the Lone Pine, Boggs, Iron Queen, and Hackberry (Anderson and Blacet, 1972a). The Blue Bell ore body is a series of overlapping lenses of granular pyrite and subordinate chalcopyrite that form a mineralized zone essentially conformable with the foliation in the Iron King Volcanics. The width of the zone is about 100 feet, and the developed length of the deposit is 1,600 feet. The ore shoots plunge steeply to the south (Lindgren, 1926, p. 143–144).

Quartz veins of Precambrian age in the Cordes area were reported by Lindgren (1926, p. 153, 156). These veins consist largely of glassy quartz with a small amount of sulfide minerals reported to contain gold and represented by a vein near Cleator. Jerome (1956, p. 125) states that the Hidden Treasure is one of the better representatives of this class of deposit in this area. According to Elsing and Heineman (1936, p. 102), the gold produced from the Hidden Treasure deposit was valued at $20,000.

The ore deposits south and east of Cleator, including the French Lily, Gray Goose, St. Johns, Golden Belt, Golden Turkey, and Silver Cord (pl. 1), are characterized by low-dipping vuggy quartz veins containing arsenopyrite, galena, sphalerite, and silver minerals. Copper-bearing minerals are subordinate. Lindgren (1926, p. 153) and Jerome (1956, p. 126) refer to these deposits as "flat" veins because of their low dips. Lindgren (1926, p. 158) reports dips at the Silver Cord mine as "less than 20°."

Jerome (1956, p. 126) has suggested that the "flat" veins are probably related to "Mesozoic-Cenozoic(?)" intrusive rocks because locally mineralized rhyolite porphyry near Cleator occupies low-dipping structures. To the north, similar rhyolite porphyry dikes intrude granodiorite stocks dated isotopically as Late Cretaceous or early Tertiary (Anderson and Blacet, 1972a), supporting the suggestion that the "flat" veins are of this age (Laramide).

Reported production from the "flat" veins has been small. According to Dunning (1959, p. 360), the Golden Belt mine produced, between 1931 and 1933, gold valued at $65,000, silver valued at $10,000, and lead valued at $5,000. R. M. Lampton acquired the property in 1934, deepened the shaft, and mined 25,000 tons of gold ore between 1934 and 1939.

The Golden Turkey deposit was located before 1900 and a shaft 100 feet deep sunk, but there was no production until 1933, when 4,000 tons of ore was run through the adjoining Golden Belt mill. The inclined shaft was deepened to the 500-foot level, and a mill was built at the mine; between 1935 and 1942, approximately 144,000 tons of ore was mined and milled. According to Dunning (1956, p. 361), "The ore was quite low-grade, with values in gold, silver, and a little copper and lead. Careful management, however, succeeded in making a little profit." The mine closed down early in 1942.

Lingren (1926, p. 158) reported that the Silver Cord vein contained silver and gold associated with some pyrite, galena, and chalcopyrite, and that by 1922, 20 or 30 carloads of shipping ore had been produced; some of it was valued at $40 per ton. Lindgren (1926, p. 159) stated that some ore was shipped from the French Lily mine in 1923, but the amount and value are not reported.

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