Revision of Precambrian Stratigraphy in the Prescott-Jerome Area, Yavapai County, Arizona

By C. A. ANDERSON, P. M. BLACET, L. T. SILVER, *and* T. W. STERN

CONTRIBUTIONS TO STRATIGRAPHY

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ILLUSTRATIONS

REVISION OF PRECAMBRIAN STRATIGRAPHY IN THE PRESCOTT-JEROME AREA, YAVAPAI COUNTY, ARIZONA

By C. A. Anderson, P. M. Blacet, L. T. Silver, and T. W. Stern

ABSTRACT

The metamorphosed volcanic, volcaniclastic, and sedimentary rocks that predate the oldest plutonic rocks in the Prescott-Jerome area (1,770±10 m.y.) are placed in the Yavapai Series, a provincial time-stratigraphic term defined as the time interval from 1,770±10 to 1,820+m.y. Two rock-stratigraphic groups are recognized; the Ash Creek Group is separated from the Big Bug Group by a major fault and a large pluton of quartz diorite. Isotopic dating now indicates that the Ash Creek Group is older. The name Big Bug Group replaces the term Alder Group, used in earlier publications on the Prescott-Jerome area. Within the Big Bug Group the Indian Hills Volcanics and Green Gulch Volcanics have been shown to be the same formation, and the latter term is retained. Where first described the Chaparral Volcanics was bounded by faults, but subsequent mapping has demonstrated that it occupies the upper part of the Spud Mountain Volcanics; so the term Chaparral Volcanics is abandoned. The Texas Gulch Formation is removed from the Yavapai Series because it is separated from the rocks of the Big Bug Group by a period of plutonism, represented by the Brady Butte Granodiorite, and subsequent erosion.

INTRODUCTION

Precambrian metamorphic rocks are exposed in four 15-minute quadrangles in the Prescott-Jerome area (figs. 1 and 2). The purpose of this report is to revise some of the stratigraphic nomenclature given in reports by Anderson and Creasey (1958) and Krieger (1965) that cover the Mingus Mountain and Prescott quadrangles (fig. 2). Anderson and Blacet completed the Mount Union and Mayer quadrangles in 1968, and the evidence requiring this revision is based on the additional mapping and on geochronological studies made by Silver

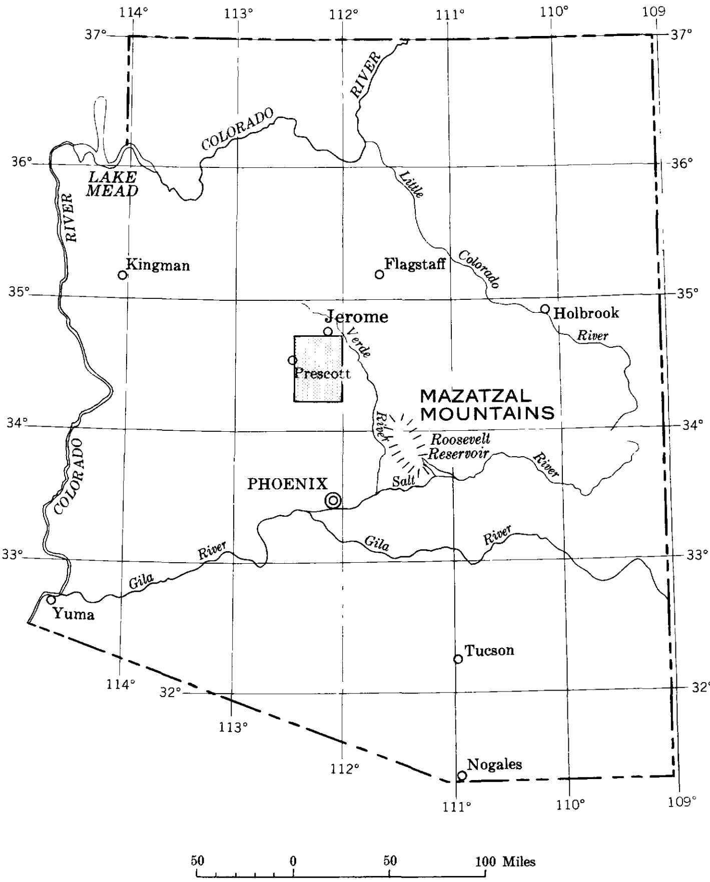


FIGURE 1.—Location of area discussed.

and Stern of U–Pb isotope systems in zircons from the Precambrian rocks.

The metamorphic rocks are largely of volcanic origin, and sufficient relict textures and structures are exposed to determine the character of the rocks before metamorphism; therefore, the prefix "meta" is not used in our stratigraphic nomenclature. Most of the Precambrian stratified rocks have been metamorphosed to the greenschist facies, but adjacent to younger intrusive rocks, higher grades of metamorphism were developed.

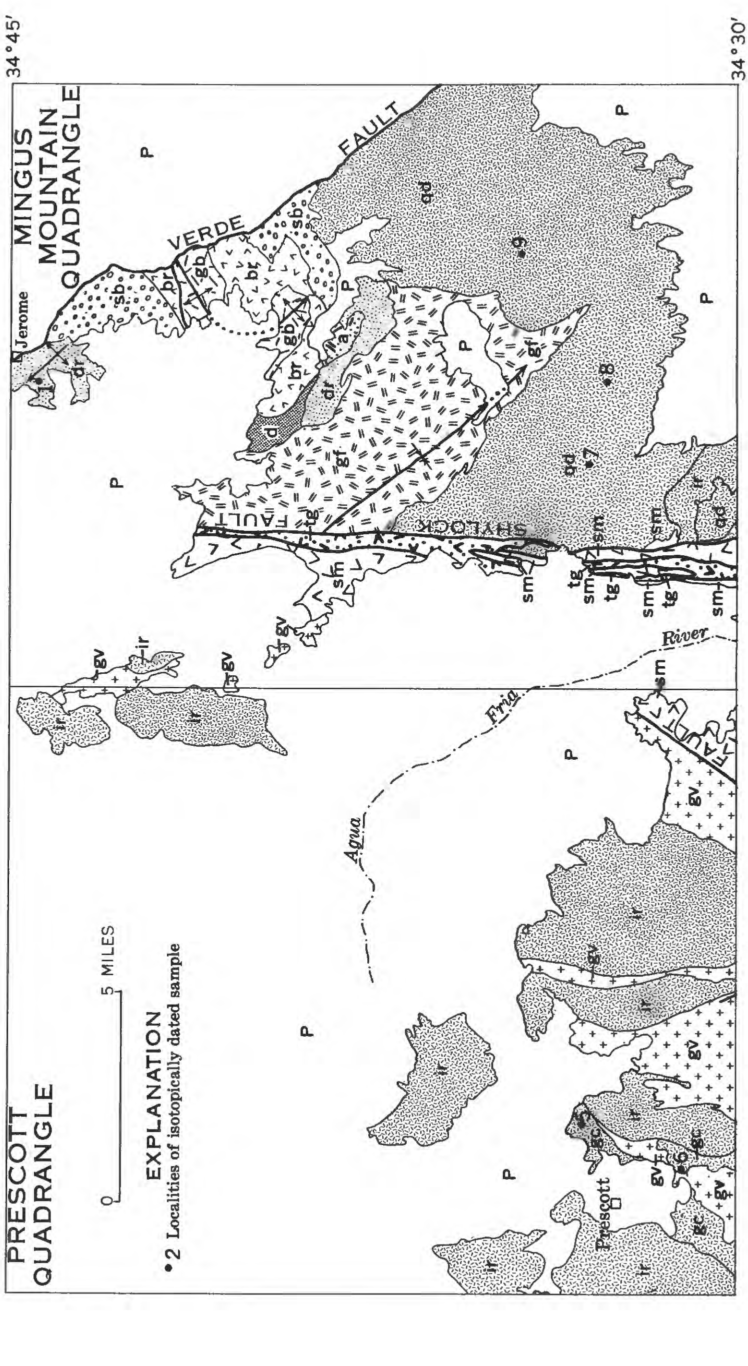
In the Mingus Mountain quadrangle, Anderson and Creasey (1958) distinguished two groups, the Ash Creek and Alder, separated by the Shylock fault, and no evidence was found to indicate the age relations of these two groups. Isotopic dating now reveals that the Ash Creek Group is the older. New evidence requires that Big Bug Group be substituted for Alder Group in the Prescott-Jerome area. Proposed revisions of formational status are limited to the Big Bug Group.

Acknowledgments.—The isotopic studies of uranium-lead systems described by Silver in this report are part of a program of research in the application of basic principles of U-Th-Pb isotope geochemistry to problems of geology. This aspect of research is supported by the U.S. Atomic Energy Commission under Project Agreement 7 under Contract AT (04-3)-767, for which this contribution is CALT-767-57, and by the California Institute of Technology, for which this is Division of Geological Sciences Contribution 1739.

ASH CREEK GROUP

The Ash Creek Group is exposed in the northern half of the Mingus Mountain quadrangle (fig. 2). The Shylock fault is the western boundary and the Verde fault is the eastern boundary. A pluton of quartz diorite intrudes the Ash Creek to the south. Paleozoic sedimentary rocks and Tertiary volcanic rocks cover the Ash Creek Group to the north and east.

The Ash Creek Group is approximately 20,000 feet thick, and neither the bottom nor the top of this sequence is exposed; the Ash Creek consists of nonfoliated basalts, rhyolitic tuffs, breccias, and flows, dacitic flows and domes, andesitic flows and breccias, and mixed andesitic and silicic bedded tuffs. Of the formations in the Ash Creek, Gaddes Basalt is the oldest formation, consisting largely of pillow lavas, and the Grapevine Gulch Formation is the youngest, consisting largely of bedded tuffs and breccias. The general character of each formation and its stratigraphic position are shown in figure 3.


34°45'
34°30'
PRESCOTT QUADRANGLE
MINGUS MOUNTAIN QUADRANGLE
EXPLANATION
•2 Localities of isotopically dated sample
0
5 MILES
VERDE FAULT
SHYLOCK FAULT
FAULT
Jerome
Prescott
Agua Fria River

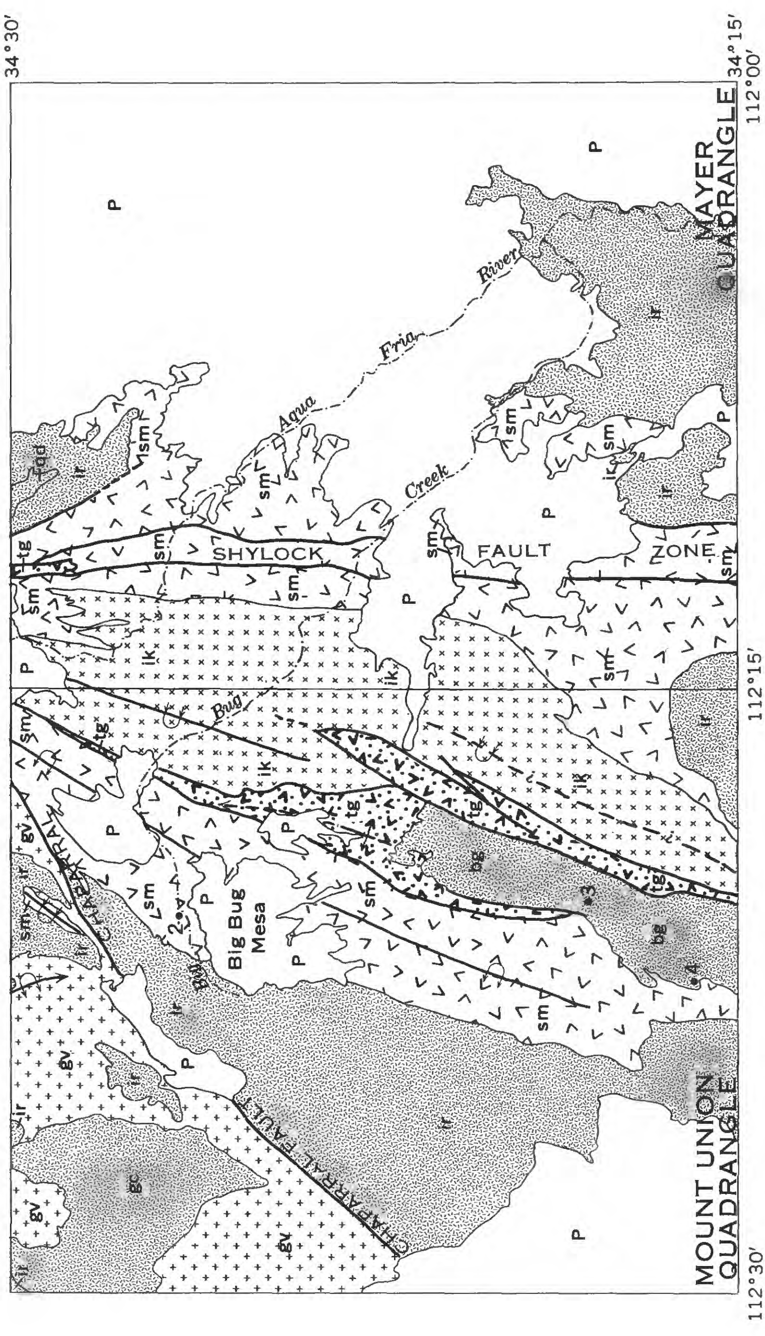


FIGURE 2.—Geologic map of the Prescott, Mingus Mountain, Mount Union, and Mayer quadrangles. (See map explanation on following page.)

EXPLANATION OF FIGURE 2

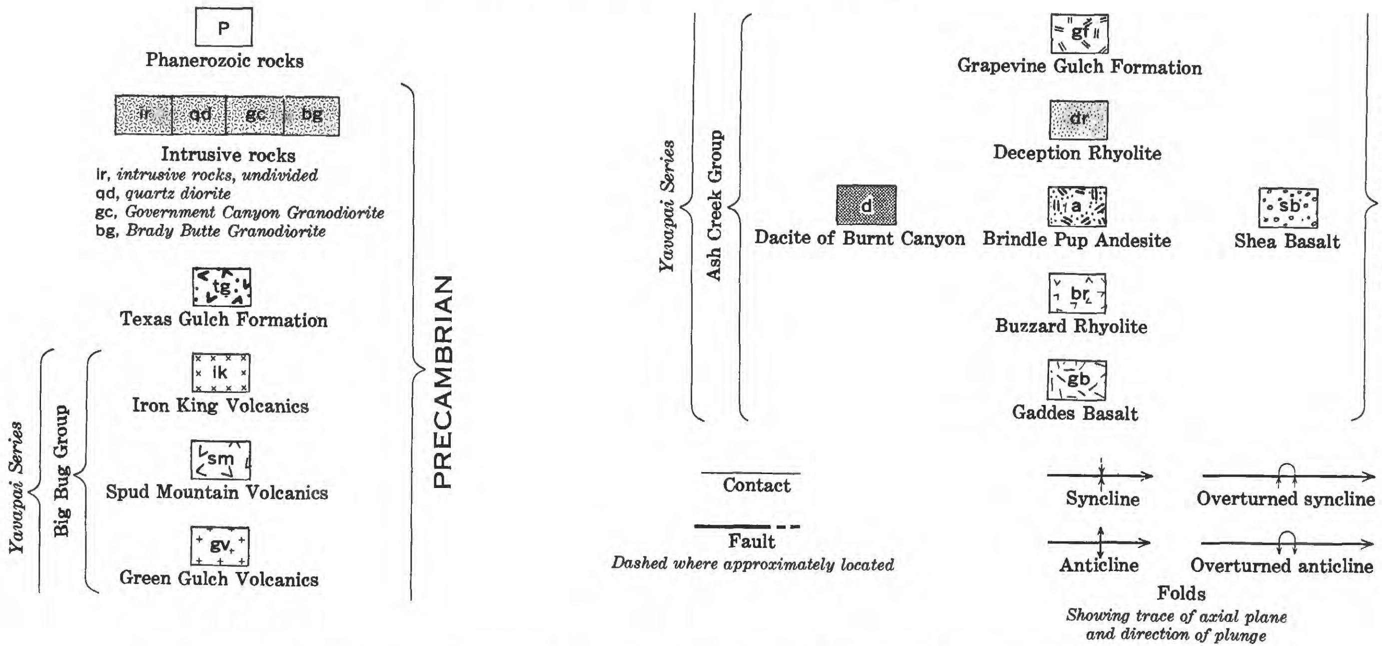


FIGURE 2.—Geologic map of the Prescott, Mingus Mountain, Mount Union, and Mayer quadrangles—Continued

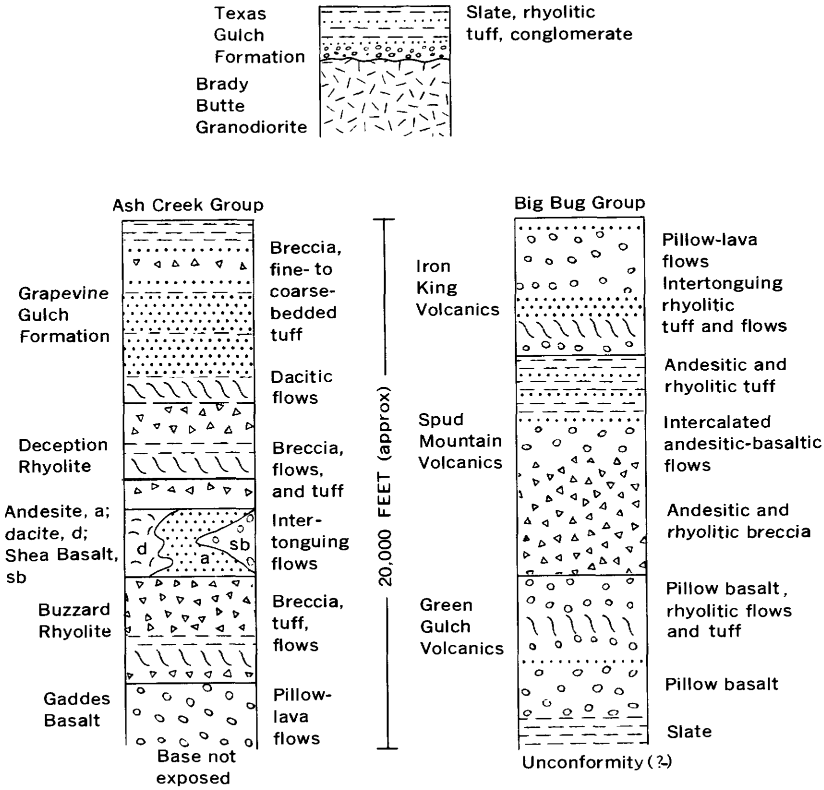


FIGURE 3.—Generalized sections of the Ash Creek and Big Bug Groups and of the Texas Gulch Formation.

BIG BUG GROUP

The Big Bug Group is exposed more or less continuously southward from the Prescott and Mingus Mountain quadrangles into the Mount Union quadrangle and western margin of the Mayer quadrangle (fig. 2). It is also exposed east of the Shylock fault zone and south of the younger pluton of quartz diorite in the Mayer quadrangle. The Big Bug Group is here named for its exposures along Big Bug Creek, originating west of Big Bug Mesa in the Mount Union quadrangle and joining the Agua Fria River in the Mayer quadrangle (fig. 2). This type locality cuts across a complete section of the Spud Mountain Volcanics and Iron King Volcanics. In the eastern half of the Mount Union quadrangle and the western part of the Mayer quadrangle, the Big Bug Group is isoclinally folded and, in general, well foliated. East of the Shylock fault zone and northwest of the

Chaparral fault, the rocks are less foliated and isoclinal folding is limited. The group is divided into three formations—the older Green Gulch Volcanics and the younger Iron King Volcanics, which contain appreciable pillow and amygdaloidal basalts, and the middle formation, the Spud Mountain Volcanics, which consists of an intertonguing complex of andesitic and rhyolitic pyroclastic rocks and amygdalodal basaltic flows (fig. 3).

In this report, data are given to document the need of substituting the name Big Bug Group for Alder Group, which Anderson and Creasey (1958, p. 20) described as containing six formations, divided into two classes. One class comprised three volcanic formations of probable known stratigraphic succession. From oldest to youngest, they were the Indian Hills Volcanics, Spud Mountain Volcanics, and Iron King Volcanics. The second class included three formations of unknown stratigraphic succession: the Chaparral Volcanics, Green Gulch Volcanics, and Texas Gulch Formation.

CHAPARRAL VOLCANICS

The Chaparral Volcanics, as originally defined, consists of a relatively narrow band of intertonguing rhyolitic and andesitic tuffaceous rocks that are strongly foliated and isoclinally folded. It occurs southeast of the Chaparral fault in the northeast corner of the Mount Union quadrangle and southeast corner of the Prescott quadrangle. The southeastern boundary is a fault, which separates the Chaparral Volcanics from the Spud Mountain Volcanics. Subsequent mapping by Anderson southward into the Mount Union quadrangle has shown that this fault dies out and that the Chaparral Volcanics is the upper part of the Spud Mountain Volcanics. Therefore, the name Chaparral Volcanics is abandoned.

GREEN GULCH VOLCANICS

The Green Gulch Volcanics is a sequence of flows and tuffaceous beds well exposed in Green Gulch northwest of the Chaparral fault in the southeastern corner of the Prescott quadrangle. Anderson and Creasey (1958, p. 31) defined this formation in their report on the geology and ore deposits of the Jerome area which included part of the Prescott quadrangle in the area surrounding the Iron King mine. The geologic mapping was done by Krieger (1965), who demonstrated that the formation consists of an eastern unit of basaltic flows and a western unit of dominantly rhyolitic flows and admixed rhyolitic and andesitic tuffaceous rocks.

In the area west of the Chaparral fault in the Prescott quadrangle, the tops of basaltic flows face either east or west, but the prevalence of west-facing flows suggests that the rhyolitic rocks to the west overlie the basaltic unit. Krieger (1965, p. 17) estimated that the Green Gulch Volcanics in that particular area is more than 5,000 feet thick. Recent mapping in the northwestern part of the Mount Union quadrangle (fig. 2) suggests a greater thickness, and 7,000 feet is more likely the minimum.

Unfortunately, in the southern part of the Prescott quadrangle and in the northern part of the Mount Union quadrangle (fig. 2), the Green Gulch Volcanics is intruded by several diverse igneous rocks so that correlations between the widely spaced stratified rocks are difficult. Krieger (1965) cautiously avoided assigning specific formation names to some of the volcanic rocks in the southern part of the Prescott quadrangle and to the west of the exposures of the type Green Gulch Volcanics; these rocks were referred to as "unnamed volcanic rocks of the Alder(?) Group."

Recent mapping of the southern extension of these unnamed volcanic rocks in the northern part of the Mount Union quadrangle has shown that these volcanic rocks can be assigned with assurance to the Green Gulch Volcanics. At the center of the northern margin of the Mount Union quadrangle (fig. 2), an anticline is exposed with a core of slate beds conformably overlain by Green Gulch basaltic flows. Excellent top determinations indicate west-facing flows west of the slate core and east-facing flows to the east. The slate beds are now considered the basal unit of the Green Gulch Volcanics, and the probability that they are the products of subareal weathering of older rocks suggests that an unconformity may exist at the base of the Big Bug Group.

The Indian Hills Volcanics was named by Anderson and Creasey (1958, p. 21) for a sequence of basaltic and rhyolitic flows exposed in the Indian Hills that protrude through Cenozoic rocks in the western part of the Mingus Mountain quadrangle. Sufficient geologic mapping by Anderson and Blacet has been done in the Mayer and Mount Union quadrangles to document that the lower part of the Spud Mountain Volcanics consists dominantly of andesitic breccias, whereas the upper part consists dominantly of thinly bedded tuffaceous rocks (fig. 3). In the Indian Hills (Mingus Mountain quadrangle), Spud Mountain andesitic breccias are conformable with the Indian Hills Volcanics that crops out west of the breccia. Exposures of the younger Spud Mountain tuffaceous beds to the east of the andesitic breccia (Anderson and Creasey, 1958, pl. 1), prove that the Spud Mountain Volcanics faces east in that area and that the Indian Hills Volcanics is older.

The small area of Spud Mountain Volcanics northwest of the Chaparral fault is exposed between east-facing Green Gulch Volcanics (on the east side of the anticline, northeastern part of the Mount Union quadrangle, fig. 2) and west-facing Green Gulch Volcanics in the type locality (west of the Chaparral fault, Prescott quadrangle). This mass of Spud Mountain Volcanics consists of the lower breccia facies, indicating that it occurs near the keel of a syncline. Unfortunately the younger intrusive rocks have destroyed much critical evidence, but the general relations strongly suggests that here Spud Mountain breccia is younger than the Green Gulch Volcanics.

The lithologic similarity of the Green Gulch and Indian Hills Volcanics, plus the strong evidence that both underlie the Spud Mountain breccia, essentially prove that the Green Gulch and Indian Hills Volcanics, consisting largely of basaltic and rhyolitic rocks, are the same formation. The name Green Gulch Volcanics was selected as the stratigraphic term to be retained, and the term Indian Hills Volcanics was dropped (Anderson and Creasey, 1967).

TEXAS GULCH FORMATION

The Texas Gulch Formation, as defined by Anderson and Creasey (1958, p. 28–30), is composed of alternating belts of bedded rhyolitic tuff and purple to gray slate, cropping out in a band about 2,500 feet wide in the Shylock fault zone in the Mingus Mountain quadrangle. The formation at this type locality is so intensely deformed that the abrupt termination of a particular slate or tuff band cannot be distinguished as a fold, a lens, or a gross boudin. Both the east and the west boundaries of the formation are faults, and internally most of the contacts between tuff and slate are probably faults. Anderson (1967) has defined this intensely sheared band as part of the Shylock fault zone in which the Texas Gulch Formation terminates abruptly in the northwest corner of the Mayer quadrangle (fig. 2).

Geologic mapping by Anderson and Blacet in the Mount Union quadrangle has revealed a similar formation with a maximum outcrop width or more than 2 miles. The eastern margin of this band of Texas Gulch Formation is in fault contact with the Iron King Volcanics, and the western margin is in fault contact with the Spud Mountain Volcanics. This band of Texas Gulch Formation extends northeastward to the northeast corner of the Mount Union quadrangle, where it has an outcrop width of about 300 feet (shown only as a fault in fig. 2). Gray slate is more common than purple slate in this belt of Texas Gulch Formation, and more arkosic beds are present than in the Shylock fault zone. Rhyolitic tuff is more common to the north than to the south, but the general lithologic similarity to the Texas

Gulch Formation in its type locality supports correlation of these two belts of slate and rhyolitic tuff.

Blacet (1966) found that the wide outcrop of Texas Gulch Formation is in depositional contact with the underlying Brady Butte Granodiorite (fig. 2). Angular blocks of the granodiorite appear in a basal conglomerate that is dominated by rounded cobbles and boulders of granophyre. Several hundred feet of arkose and feldspathic sandstone grades upward into bedded rhyolitic tuff and gray slate, with minor interbeds of pebble conglomerate. Anderson (1968, p. 14) concluded that this uncomformable relationship to the Brady Butte Granodiorite proved that the Texas Gulch Formation is the oldest formation in the Alder Group. This interpretation was based on the assumption that the Texas Gulch Formation is the correlative of the slate sequence in the core of the anticline in the Green Gulch Volcanics that is exposed near the north-central margin of the Mount Union quadrangle (fig. 2). This same lithologic correlation was made in the Prescott quadrangle by Krieger (1965) on the advice of Anderson during the period when mapping was in progress in the Prescott and Mingus Mountain quadrangles.

The isotopic data and the field relations indicate that the Texas Gulch Formation is not the oldest formation in the Alder Group; rather, the Texas Gulch Formation in this area must be younger than the Big Bug Group.

BRADY BUTTE GRANODIORITE

The Brady Butte Granodiorite is exposed in the core of a major faulted anticline that plunges gently northward (fig. 2). The granodiorite is somewhat gneissic, with local zones of mylonite (Blacet, 1966). The southwestern part of the Brady Butte Granodiorite is coarsely crystalline to porphyritic granodiorite (loc. 4, fig. 2) and is clearly intrusive into the Spud Mountain Volcanics. Our first interpretation was that the porphyritic facies is younger than the Brady Butte Granodiorite, in harmony with the conclusion that the Texas Gulch Formation is the oldest unit in the Big Bug Group; however, isotopic measurements made by two authors, Silver and Stern, have shown that the Brady Butte Granodiorite and the southerly porphyritic granodiorite are essentially the same age. Mapping by Blacet failed to reveal clearcut intrusive relations between the porphyritic and nonporphyritic granodiorites, and chemically these two facies are indistinguishable. These data indicate that the Brady Butte Granodiorite at its type locality, where it uncomformably underlies the Texas Gulch Formation, is also younger than the Spud Mountain Volcanics, the middle formation of the Big Bug Group (fig. 3).

ISOTOPIC STUDIES

Uranium-lead isotope systematics in cogenetic zircon families (Silver and Deutsch, 1963) have been studied from samples of many different igneous rock units in the local stratigraphic column. The analytical data are too extensive and complex for effective presentation here and will have to be published separately.

There are a number of significant age relations apparent in the isotope data which bear directly on the problems of the Precambrian stratigraphy. They are presented in a summary form in figure 4, a Pb^{206}/U^{238}–Pb^{207}/U^{235} concordia diagram (Wetherill, 1956). Two or more fractions of zircon from each rock unit, generally from a single sample and differing distinctly from each other in uranium concentrations, have been analyzed. In general, the individual fractions of each family differ significantly from each other in their daughter-parent isotope ratios, indicating some isotopic disturbance. On the concordia diagram, the maximum extent and direction of the observed differences between the zircon fractions are represented by lines (chords). From the extrapolation of these lines to upper intersections with concordia, the time of initiation of the isotope system (zircon crystallization) is inferred. Where the zircon families appear to be very similar in age and in degree of isotopic disturbance (discordance), lateral displacement of plotted positions on the diagram is an indicator of slight differences in ages. From these systematic relations, it is possible to develop interpretations of apparent ages which are quite precise and hence capable of remarkable resolution. The general basis for this approach has been established by Silver and co-workers elsewhere (Silver, 1963a, b, and unpub. data).

The general pattern of isotope relations in zircons from two volcanic units and three plutons (fig. 4) indicates that all samples are discordant and accordingly have been disturbed. The degree of discordance varies from about 5 to 50 percent. Despite the discordance, all the family lines, each representing a rock unit, extrapolate to an apparent age interval of between 1,760 and 1,820 m.y. (million years). Stratigraphically significant age resolution can be made within this interval.

The zircons obtained from the Spud Mountain Volcanics and Deception Rhyolite can be attributed to the crystallization episodes of each of the host rocks, by virtue of their morphology, trace-element characteristics, and certain isotope systematics. Zircons from a quartz porphyry facies in the upper part of the Deception Rhyolite of the Ash Creek Group near Jerome yield an apparent age of 1,820±10 m.y. Zircons from a rhyolite flow in the upper part of the Spud Mountain Volcanics north of Big Bug Mesa are apparently 1,775±10 m.y. old.

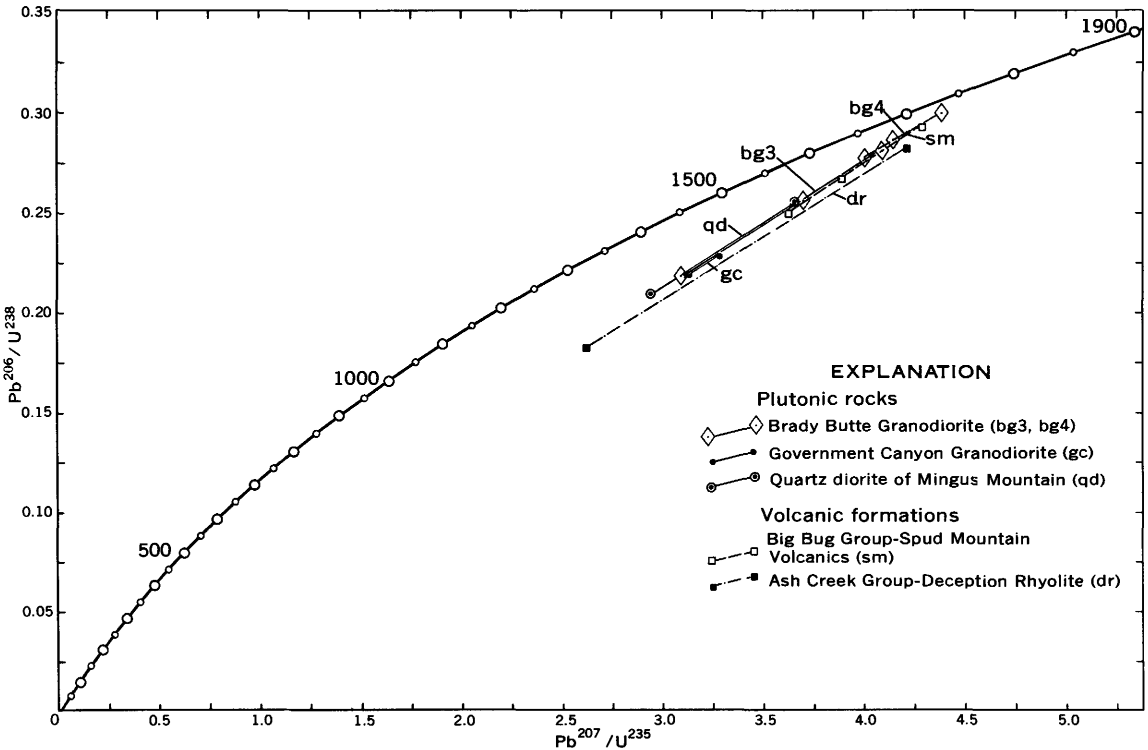


FIGURE 4.—Concordia diagram of Pb^{206}/U^{238}-Pb^{207}/U^{235} systematics in cogenetic zircon suites from Precambrian volcanic and plutonic rocks.

These ages suggest that a large part of the Big Bug Group is distinctly younger than one of the younger formations in the Ash Creek Group. Provisionally (lacking adequate field relations to test the assignment properly), the entire Big Bug Group is considered to be younger than the Ash Creek Group.

The Brady Butte Granodiorite has been sampled at two localities, and the two chords representing the zircon families yield similar ages of 1,770±10 m.y. The porphyritic phase of the Brady Butte Granodiorite (fig. 2, loc. 4) has intruded the Spud Mountain Volcanics. The ages of the Brady Butte Granodiorite and the Spud Mountain rhyolite zircons are so similar that they overlap in apparent age assignment, and this indicates the essential synchroneity of plutonism and extrusive volcanism at the time of accumulation of the Big Bug Group.

Isotope relations are indicated for two other areally significant plutons in figure 4. The quartz diorite which intruded the Ash Creek Group in the southern part of the Mingus Mountain quadrangle has an apparent age of 1,760±15 m.y. This provides a minimum age for the Ash Creek Group. The Government Canyon Granodiorite intrudes the Green Gulch Volcanics of the Big Bug Group and yields an apparent age of 1,770±15 m.y. The granodiorite is a late synkinematic or postkinematic intrusive which suggest that the major part of the deformation of the Big Bug Group had been completed prior to the emplacement of the granodiorite.

All three plutons are remarkably similar in the ages interpreted from the isotope relations and indicate that synchronous plutonic activity occurred in the area discussed in this report. Late volcanism was closely related in time and space to the major regional plutonic episode.

ABANDONMENT OF NAME ALDER GROUP IN THIS AREA

Wilson (1939, p. 1121 and 1158) applied the term Alder Series to the northern exposures of Precambrian volcanic and sedimentary rocks west of the Shylock fault (fig. 2) because of their lithologic similarity to his Alder Series in its type section in the Mazatzal Mountains about 60 miles southeast of the Mingus Mountain quadrangle (fig. 1). Anderson and Creasey (1958, p. 20) noted the lithologic similarity of their Texas Gulch Formation to the Alder Series in the Mazatzal Mountains, but they pointed out that the map by Wilson (1939, p. 1158) of the Mingus Mountain area included their Spud Mountain Volcanics in his Alder Series. They concluded that it was desirable to retain Wilson's term Alder for all the sedimentary and volcanic rocks exposed west of the Shylock fault or south of the pluton of quartz diorite (fig. 2). The term Alder Group was then used because of its subdivision into six formations.

The lithologic correlation of the Texas Gulch Formation with Wilson's type Alder Series may be justified but future field and isotopic studies may prove the contrary. It is desirable to discontinue use of the term Alder Group in the Prescott-Jerome area because the Texas Gulch Formation is separated from the Green Gulch Volcanics, Spud Mountain Volcanics, and Iron King Volcanics by a period of plutonism and subsequent erosion. The name Big Bug Group is proposed as a substitute for Alder Group in this area.

YAVAPAI SERIES

Jaggar and Palache (1905) first designated the metamorphic rocks in the Prescott-Jerome area the Yavapai schist, and Wilson (1939, p. 1119) extended this term to the Mazatzal Mountains, modifying it to Yavapai Group because schistosity is only local. Anderson and Creasey (1958, p. 9) used the term Yavapai Series in keeping with the rules of stratigraphic nomenclature at that time, as two groups of rocks were involved. Recently, Anderson (1968) used the term Yavapai Supergroup in order to follow the Code of Stratigraphic Nomenclature (Am. Comm. on Strat. Nomenclature, 1961); the term was used as a rock-stratigraphic unit because no evidence was available to place the two groups in stratigraphic succession.

With the geochronological data now available, it is possible to use the term Yavapai Series as a time-stratigraphic term in a provincial sense to indicate the length of time represented by the Ash Creek and Big Bug Groups. The Ash Creek Group yields an age of 1,820 ± 10 m.y. based on zircon dating of quartz porphyry in the upper part of the Deception Rhyolite (fig. 2, loc. 1). The data from a rhyolitic rock in the Big Bug Group (fig. 2, loc. 2) indicates an age of 1,775 ± 10 m.y. The isotopic dates of approximately 1,770 ± 10 m.y. obtained from the Brady Butte Granodiorite and associated porphyritic granodiorite (fig. 2, locs. 3 and 4) give the younger time limit for the age of the Big Bug Group. Thus, the Yavapai Series can be defined as the time interval from 1,770 ± 10 to 1,820 + m.y.

With the restriction of the Yavapai Series to rocks no younger than 1,770 ± 10 m.y., the Texas Gulch Formation is not included in the Yavapai Series. The Alder Series in the Mazatzal Mountains should not be included in the Yavapai Series at this time because no isotopic dates are available. Silver (1965) has dated the Red Rock Rhyolite in the Mazatzal Mountains as 1,715 ± 15 m.y., well below the suggested younger limit for the time interval of the Yavapai Series. Silver (oral presentation at International Conference "Geochronology of Precambrian stratified rocks," Edmonton, Alberta, June 12–14, 1967) has suggested, provisionally, a major time distinction between the older stratified rocks of northern and southern Arizona based upon

U–Pb isotope relations in zircons. The central Arizona relations described here provide an important element in the construction of regional Precambrian stratigraphic relations.

Butler and Wilson (1938, p. 11) divided the Precambrian rocks of Arizona into older and younger Precambrian. The younger Precambrian rocks include the unmetamorphosed Grand Canyon Series and Apache Group whereas the older Precambrian rocks include the metamorphosed rocks below. The terms "older" and "younger" were used in a provincial sense to indicate that for a particular area, rocks are early or late in the Precambrian sequence in Arizona. With the isotopic information now available for the Precambrian rocks in Arizona, the distinction between "older" and "younger" is not needed. In the Prescott-Jerome area, the isotopic dates of the Yavapai Series and the younger plutons are preferable substitutes for "older Precambrian."

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