

Geologic Map of the Fairbank 7 1/2' Quadrangle Cochise County, Arizona

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DIGITAL GEOLOGIC MAP DGM-50 v 3.0

September 2018

Arizona Geological Survey

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Manuscript v 3.0 approved for publication in September 2018
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This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program, award no. #04HQAG0072. Revised and re-released with funding from the USGS National Geological and Geophysical Data Preservation Program, award no. G17AP00114. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. The Arizona Department of Water Resources provided funding for map revisions depicted in DGM-50, version 2.0.

Recommended Citation. Ferguson, C.A., Shipman, T.C., Pearthree, P.A., Moore, E.N., Richard, S.M., Spencer, J.E., Youberg, A., Cook, J.P., and Haddad, D.E., 2018, Geologic Map of the Fairbank 7½' Quadrangle, Cochise County, Arizona: Arizona Geological Survey Digital Geologic Map 50 (DGM-50), version 3.0, 1 sheet, layout scale 1:24,000, with text.



THE UNIVERSITY OF ARIZONA
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Introduction

The Fairbank map area is dominated by an Upper Cretaceous plutonic-volcanic complex that is closely associated with silver-rich, porphyry ore deposits of the Tombstone district (Goodale, 1927; Butler et al., 1938; Newell, 1974; Devere, 1978; Williams, 1980) located directly east of the map area. The volcanic rocks overlie Lower Cretaceous siliciclastic strata of the Bisbee Group with angular unconformity. The older rocks were folded into northwest-striking folds that show evidence for two phases of deformation. The Upper Cretaceous volcanics are moderately to gently tilted to the northwest forming two low-lying, southwest-striking horst blocks. A fairly major southeast-side-down normal fault, of probable middle Cenozoic age, is interpreted to cross the San Pedro valley diagonally from northeast to southwest just to the southeast of the northwestern horst block. A panel of volcanoclastic conglomerate of probable middle Cenozoic age is barely preserved overlying the volcanics along the northwestern flank of the northwestern horst block just to the north of this map area (Shipman and Ferguson, 2005). A small outcrop of similar conglomerate is tentatively identified overlapping the southeastern horst block. Another strip of conglomerate occurs parallel to and along the crest of the northwestern horst block, but this conglomerate dips steeply to the southeast and is bounded by a gently northwest-dipping normal fault. The age relationship between the two oppositely dipping conglomerate sequences and faults is unknown.

The principal volcanic unit in the area is the Uncle Sam Tuff, a quartz latite that was originally interpreted as a rhyolite flow (Church, 1903), reinterpreted as an intrusive (Ransome, 1904; Jones and Ransome, 1920), and then widely regarded as a lacolith-shaped intrusive complex named the Uncle Sam Porphyry (Butler et al., 1938; Gilluly, 1945; 1956). Drewes (1971) recognized the pyroclastic nature of the porphyry and, Lipman and Sawyer (1985) and Moore (1993) delineated the boundaries of a caldera complex. Moore (1993) formally renamed the unit the Uncle Sam Tuff. Our work shows that, although most of the unit is an ash-flow tuff, there are also significant areas of porphyry that intrude the Uncle Sam Tuff. The lacolith style emplacement model of Gilluly (1945) was partially correct.

Stratigraphy

The study area is dominated by Mesozoic rock units consisting of Lower Cretaceous siliciclastic sedimentary rocks overlain by Upper Cretaceous volcanic rocks. Much of the area lies within an Upper Cretaceous silicic caldera complex.

Lower Cretaceous Bisbee Group

In its type locality in the Mule Mountains of southern Cochise County, the Bisbee Group consists of at least 5,000 feet of sandstone, shale, siltstone, conglomerate, and limestone (Ransome, 1904). The basal unit, the Glance Conglomerate is overlain by two siliciclastic units, the Morita (older) and Cintura Formations (younger) with an intervening limestone unit, the Mural Limestone. The unit was deposited in a complex series of generally northwest-striking rift basins, where depositional environments ranged from proximal alluvial fan to alluvial and marginal marine and/or lacustrine to deep-water marine and lacustrine (Bilodeau, 1982; Dickinson and Klute, 1987). The two main siliciclastic formations of the Bisbee Group are virtually indistinguishable. If the intervening Mural Limestone is not present, previous workers (Gilluly, 1956 and Hayes, 1970) recommend that no attempt be made to differentiate the two. This is the case along the San Pedro Valley in the Tombstone area. Gilluly (1956) believed that the Mural Limestone was not present north of the Mule Mountains, and referred to most of the rocks in the Tombstone area as the Bisbee Formation (undifferentiated) because no significant intervals of limestone are found in this area. However, after Creasy (1967), and Archibald (1987) mapped and described the Mural Limestone in the Whetstone Mountains to the north, it became clear that the Mural Limestone interval was either never deposited or was deposited and then later removed by erosion in the Tombstone area. Just to the north of the map area, Shipman and

Ferguson (2005) reinterpreted a limestone that had been mapped as Epitaph dolostone (Gilluly, 1956; Moore, 1993) as Mural Limestone. Minor thin limestone units with sparse molluscan fauna are present within the Bisbee Group in the Tombstone Hills (Butler et al., 1938; Gilluly, 1956; Force, 1996), but no serious attempt has been made to correlate these rocks with the Mural Limestone. Based on poorly preserved fossils and regional arguments, Stoyanow (1949) believed that the Bisbee Group of the Tombstone Hills was all part of the uppermost unit of the Bisbee Group, the Cintura Formation. Force (1996) divided the Bisbee Group of the Tombstone area into informal upper and lower divisions with a lower division consisting primarily of coarse-grained breccia and conglomerate, a unit that Gilluly (1956) correlated with the Glance Conglomerate.

Bisbee Group in the map area is mapped simply as undifferentiated siliciclastic Bisbee Group (Ks). The base is not exposed and the upper contact is an angular unconformity. The Bisbee Group in the study area is strongly folded and was probably deeply eroded prior to deposition of Upper Cretaceous volcanics. It is therefore possible that all of the upper Bisbee Group in this area, including the Mural and Cintura formations was removed. In support of this interpretation, just to the north of this map area a sequence of Bisbee Group siliciclastic strata is overlain by Mural Formation (Shipman and Ferguson, 2005) and correlated with the Morita Formation.

The Bisbee Group of the study area consists of complexly intertonguing sequences of thin- to thick-bedded, cross-stratified and plane-bedded, quartz sandstone, feldspathic quartz sandstone, and lithic-feldspathic quartz sandstone interbedded with gray-green to red siltstone, mudstone, silty mudstone and shale, locally with abundant calcareous nodules and irregularly thin- to medium-bedded, discontinuous impure limestone, and limestone pebble conglomerate. Two lithofacies, ranging in thickness from 5 to 150m, are recognized, each representing approximately 50% of the map unit, and each characterized by the dominance of specific lithologies: 1) gray-green mudstone and lithic-feldspathic-quartz sandstone, and 2) red shale or mudstone and quartz sandstone. The two lithofacies occur in repeating cycles with the red shale and quartz sandstone units typically sharply overlying the lithic-feldspathic-quartz sandstone and dark mudstone units. Sparse, rounded to well-rounded, clast-supported and matrix-supported, medium- to thick-bedded, sandy matrix, pebble-cobble conglomerate beds are associated with both lithofacies. Clasts in the conglomerate consists of quartzite, argillite, vein quartz, with sparse granitoid, limestone, and felsic volcanics.

The gray-green mudstone and lithic-feldspathic quartz sandstone lithofacies is characterized by thin- to medium-bedded, moderately to moderately poorly-sorted, grayish green, argillaceous sandstone interbedded with dark colored mudstone and siltstone. Sandstone is typically massive, but may include ripple-laminated intervals. The lithofacies is interpreted as a distal alluvial to deltaic and distributary channel depositional environment. Some of the sandstone units may be turbidites.

The red shale and quartz sandstone lithofacies typically consist of moderately to well-sorted, light colored, less argillaceous, commonly complexly cross-stratified sandstone interbedded with reddish siltstone, mudstone and shale. Sandstone is typically quartzose with quartz cement. Calcareous nodules, irregularly bedded impure limestone, and limestone pebble conglomerate beds are found almost exclusively associated with the red shale and mudstone. The red shale and quartz sandstone lithofacies are interpreted as alluvial deposits grading into marginal marine and/or lacustrine high-energy beach sequences. The associated pedogenic carbonate units suggest a semi-arid environment.

Upper Cretaceous volcanics

Upper Cretaceous volcanic rocks overlie the Bisbee Group with pronounced angular unconformity and form a gently northwest-dipping pile several hundred meters thick. The lower part of the sequence consists of andesitic lava overlain and intruded by rhyolite lava and lithic tuff that was collectively referred to as the Bronco volcanics by Gilluly (1945; 1956). These rocks are overlain by the Uncle Sam Tuff, a phenocryst-rich ash-flow tuff of quartzite latite composition that forms resistant rounded peaks and ridges. The older volcanics form low, rounded hills, and the rocks are pervasively altered. Propylitic alteration is ubiquitous with pervasive chloritic alteration of mafic phenocrysts, and abundant epidote-coated joints and fractures.

Andesite

Andesite lava and a probable andesitic intrusive complex, mapped collectively as unit Ka, directly overlie and intrude the Bisbee Group in the southern part of the map area. These rocks correlate with the andesite portion of the Bronco Hill volcanics of Gilluly (1956). The southernmost exposures of these rocks represent a intrusive complex composed of andesitic flows interspersed with a confusing array of Bisbee Group sandstone and argillite blocks most of which are oriented as if they were not significantly disrupted relative to nearby exposures of Bisbee Group outcrops. In the southerly adjacent Lewis Springs map area (Pearthree et al., 2005), the contact between the Bisbee Group and the andesite is characterized by large areas of sedimentary rock intruded by andesitic dike swarms that coalesce into zones dominated by andesite with scattered sandstone and argillite blocks. This intrusive complex is intruded by a complex series of younger andesitic dikes of various composition, and by a relatively massive stock of andesite porphyry (Kap) that is in turn sparsely intruded by additional fine-grained andesitic dikes (Kai). The andesite porphyry stock was mapped as part of the Uncle Sam Porphyry by Gilluly (1956), and as a dacite lava by Moore (1993). Farther north and up-section through the andesite lava sequence, dikes become less abundant.

The andesite lava forms a monotonous pile of amalgamated flows locally with thin mafic pyroclastic and volcanoclastic sandstone and conglomerate interbeds. Petrographically, the andesite lavas are characterized by small (<2 mm) mafic phenocrysts that are usually altered beyond recognition and therefore of little use for differentiating flows. Where recognizable, the mafic phenocrysts are dominated by hornblende, but pyroxene phenocrysts are also present. Attempts to map individual flows and sequences of similar lavas are severely hampered by complex interfingering of different flow types, cross-cutting dikes of varying composition, poor exposure, and uncertain structural relationships. The resulting map depicts the entire unit as undifferentiated andesite lava, a solution required by the scope of this mapping project. Detailed field descriptions of the rocks are available as part of a digital database accompanying this map and may be of use to investigators working on specific problems or using smaller scale maps.

In the database, individual outcrops of the andesite unit (Ka) are subdivided into three general types based on the abundances and size ranges of the plagioclase phenocrysts. The symbols and general descriptions are: Kfx) fine-grained, phenocryst-rich andesite containing >10%, but usually >25%, 0.5-2.0 mm, but usually <1.0 mm plagioclase phenocrysts, Kfp) fine-grained, phenocryst-poor andesite containing <10%, but usually <5%, 0.5-2.0 mm, but usually <1.0 mm plagioclase phenocrysts, and Kmx) flows with discrete blocks or zones of the Kfx and Kfp types mixed with medium-grained, moderately phenocryst-rich andesite containing 10-25%, 1.5-3.0 mm plagioclase phenocrysts. In the northern part of the lava field, flows of the fine-grained phenocryst-poor and phenocryst-rich andesite lava dominate with only thin intervals of the Kmx type, but to the south, Kmx dominates in an area that includes abundant blocks ranging in size from 1 to 100 m of Bisbee Group sedimentary rocks. In some areas, the andesite and sedimentary rock are so intimately swirled together that descriptive units, Kmx-s or Kfx-s are used in the database. These zones probably represent vent complexes. In general, to the north, flows of the fine-grained phenocryst-poor and phenocryst-rich andesite (Kfx and Kfp) dominate.

To the south, the medium-grained andesite (Kmx) dominates in an area that appears to be an intrusive complex. Additional descriptive headings of Kmx-s or Kfx-s apply to zones of andesite containing abundant, unmappable inclusions of sandstone and argillite.

On the west side of San Pedro River, a distinctively different suite of andesitic rocks underlies the Uncle Sam Tuff. This andesitic complex (Kdx) consists of lava flows interbedded with nonwelded and welded pyroclastic rocks of phenocryst-rich (generally greater than 20% phenocrysts), coarse-grained (up to 4mm) plagioclase-porphyrific andesite with pyroxene phenocrysts. Locally, the complex also includes phenocryst-poor basaltic and basaltic andesite lavas. No age relationship between these lavas and the phenocryst-poor, mostly fine-grained andesite east of the river is known.

Rhyolite lava

Two types of rhyolite lava, an aphyric lava (Kra) and a phenocryst-poor lava (Kr) overlie the andesite sequence. The aphyric rhyolite is mostly or entirely extrusive, including abundant autobreccia and heterolithic tuff breccia in the Graveyard Gulch area. Farther east, in the Charleston Lead Mine area, a phenocryst-poor rhyolite lava (Kr) overlies and/or intrudes the andesite. The phenocryst-poor rhyolite also intrudes the tuff of Charleston.

Tuff of Charleston

The tuff of Charleston is a new name proposed for a distinctive, moderately phenocryst-poor, quartz-feldspar-biotite rhyolite ash-flow tuff that crops out throughout the Charleston area. The tuff was mapped as the quartz latite tuff of the Bronco volcanics by Gilluly (1956), and as part of a generic rhyolite unit including all rhyolite tuffs and lava in the Charleston area by Moore (1993). Phenocrysts up to 2-3mm comprise less than 10% of the tuff. The tuff overlies the aphyric rhyolite (Kra), and is intruded by the rhyolite (Kr). The tuff of Charleston is divided into two map units. The main part consists of welded tuff (Kt) containing 1-20% lapilli lithic fragments of andesite lava, sandstone, argillite, and rounded quartzite pebble-cobble conglomerate. A subordinate unit is a clast-supported megabreccia (Ktx) dominated by clasts up to 100 m of andesite lava, but also containing lesser amounts of the same types of clasts present in the matrix-supported tuff. Most of the andesitic clasts in the megabreccia display the same heterogeneous phenocryst abundances and profusion of Bisbee Group inclusions recognized in the intrusive complex of the andesite map unit (Ka) directly east of Bronco Hill.

The presence of a megabreccia unit within the tuff of Charleston suggests that these rocks may lie within a caldera complex or, at least, near an escarpment capable of delivering large amounts of debris into the tuff during its emplacement. The tuff of Charleston megabreccia thickens to the east towards the Charleston Lead Mine where it is abruptly bounded by andesite lava along a northwest-striking contact. This contact, which runs through the Charleston Lead Mine, is tentatively interpreted as a southwest-facing caldera margin.

Uncle Sam Tuff and the porphyry of Fairbank

The Uncle Sam Tuff is a phenocryst-rich, plagioclase, potassium feldspar, quartz, biotite, hornblende phyric ash-flow tuff that has a long history of investigation. The unit was originally interpreted as a rhyolite flow (Church, 1903), and then reinterpreted as an intrusive (Ransome, 1904; Jones and Ransome, 1920). Butler et al. (1938) named the unit the Uncle Sam Porphyry, and Gilluly (1945, 1956) interpreted it as a lacolith-shaped intrusive complex. Gilluly (1945) described the porphyry in detail with special reference to large amounts of coarse-grained lithic breccia, and its remarkably fine-grained, essentially vitric matrix. Gilluly (1945) recognized that the vitric matrix was an enigmatic problem that could not be adequately explained by rapid cooling of the porphyry adjacent to the lithic blocks, but still interpreted the body to be intrusive based on the sharp, apparently intrusive contacts it displayed with older rocks. Gilluly (1945) interpreted the breccia zones with vitric matrix as evidence that the porphyry was emplaced into a

major Laramide thrust fault zone. Drewes (1971) recognized the pyroclastic nature of the matrix and, based on its great thickness and extensive swarms of lithic breccia, interpreted it as part of a caldera complex. Newell (1974) studied the unit in some detail, describing its pyroclastic texture, and showed that parts of it intrude older rocks, as had been observed by Gilluly (1945; 1956). Lipman and Sawyer (1985) and Moore (1993) delineated the boundaries of a caldera complex, and Moore (1993) formally renamed the unit the Uncle Sam Tuff.

Based on the same observations advanced by Drewes (1971), Lipman and Sawyer (1985), and Moore (1993), our mapping shows most of the unit mapped as the Uncle Sam Tuff is indeed an ash-flow tuff. However, there are also significant areas of porphyry that intrude the tuff. This porphyry, herein named the porphyry of Fairbank occurs in two areas. In the north, near the settlement of Fairbank, the porphyry forms a northerly elongated stock. Intrusive contacts with the Uncle Sam Tuff and older rocks are preserved, and near these the porphyry is flow-foliated and locally has vitric matrix. To the south, northeast of the Charleston Lead Mine, the porphyry intrudes the Uncle Sam Tuff as a series of northeast-elongated anastomosing sills. Although exposure is limited, the complex resembles the “Christmas Tree” laccoliths of Corry (1988) and Maynard (2005). The lacolith style emplacement model of Gilluly (1945) appears to be partially correct, and the intrusive nature of many of the unit’s contacts that puzzled previous workers in areas to the east of this map area (Gilluly, 1945; Newell, 1974; Force, 1996) might be explained by the presence of similar bodies of intrusive porphyry in these areas.

The Uncle Sam Tuff and the porphyry of Fairbank are virtually identical in terms of phenocryst content. The intrusive porphyry (Krd) is distinguished from the tuff by its lack of pyroclastic texture and pyroclasts (fiamme and lithics) and the even distribution of its unbroken phenocrysts. Phenocrysts in the tuff are consistently smaller than those in the porphyry, typically subhedral to anhedral, and distributed chaotically. The tuff also contains abundant pumice lapilli along with locally abundant sandstone, argillite, and fine-grained andesitic lithic fragments. Both units contain 1-10%, 1-10cm, rounded, irregular, fine-grained dioritic inclusions, as do two other important intrusive units in the area, the quartz monzonite of Bronco Hill (Pearthree et al., 2005), and a swarm of coarse-grained, andesite porphyry dikes (Kad).

Marvin et al. (1973) report a K/Ar biotite age of 73.5 ± 2.80 Ma for the Uncle Sam tuff from a sample along the western edge of the map area.

Younger conglomerate

Just to the north of the map area (Shipman and Ferguson, 2005), a narrow strip of gently northwest-tilted volcanoclastic conglomerate and pebbly sandstone overlaps the northwestern flank of the western horst block. One small exposure of similar conglomerate, tentatively correlated with this conglomerate, is mapped along the northwestern flank of the eastern horst block near the center of this map area. The conglomerate is poorly exposed, with no preserved bedding, so it is possible that it is merely a strongly cemented colluvial deposit.

Caldera geology

The Tombstone silicic caldera complex, source to the Uncle Sam Tuff, is described by Lipman and Sawyer (1985) and Moore (1993) and includes most of the map area. The great thickness and areal extent of the tuff indicates that most of the ash-flow tuff lies within the caldera. Large areas of megabreccia, particularly in the northwest further attest to the intracaldera nature of the unit.

Southern margin

Mid-Cenozoic tilting exposes the floor of the caldera as a gently northwest-dipping, irregular surface striking southwest across the southern portion of the map area. Lipman and Sawyer (1985) and Moore (1993) show the southern caldera margin extending well to the south including a large area of pre-caldera volcanics, and Bisbee Group as part of the floor. Since there

is no evidence of a ring fracture zone, or major structural offset in the pre-caldera rocks to the south of the floor, and since the pre-caldera rocks in the area are intruded by two granitic stocks, this extension seems reasonable. This evidence is, however, not definitive. For example, if the southern margin of the caldera were a north-tilted trap door structure, there might be little evidence of a ring fracture zone or major structural offsets along the margin. North-facing trap door margins of the Upper Cretaceous Tucson Mts and Roskrige Mts calderas (Lipman, 1993; Ferguson et al., 2000) are not delineated by conspicuous ring fracture zones or faults. In addition, the lack of megabreccia zones within the Uncle Sam Tuff in the southern part of the caldera fill indicates that there may not have been a major caldera-bounding escarpment along the southern margin, a feature that is shared by the intracaldera tuff of Sharp Peak along its southern caldera margin (Ferguson et al., 2000), and to a certain degree by the intracaldera Cat Mt Rhyolite in the southern Tucson Mts (Lipman, 1993).

The granitic stocks that intrude pre-caldera rocks to the south of the caldera floor in the Tombstone Hills might not be related to caldera formation and therefore may have little bearing on the delineation of the caldera margin.

Eastern margin

The eastern margin of the Tombstone Hills caldera complex is a moderately west-dipping buttress unconformity overlapped by Uncle Sam Tuff. Most of this north-striking contact lies to the east of the map area. Moore (1993) delineates a west-side-down structural margin for the caldera to the east of this topographic scarp and interprets it to be intruded by the Scheffelin Granodiorite.

Western margin

Lipman and Sawyer (1985) and Moore (1993) identify a gently east-dipping topographic escarpment overlain by the Uncle Sam Tuff in the hills west of the San Pedro River as the western caldera margin. Uncle Sam Tuff lying to the west of this contact is referred to as outflow facies and to east as intracaldera facies. A change in dip of the eutaxitic foliation in the Uncle Sam Tuff from gently west-dipping to the west to moderately east-dipping to the east (Moore, 1993) is offered as further evidence for a caldera margin in this area. Our mapping, however, shows much of the tuff to the east of the escarpment with gently northwest-dipping foliation. We identified easterly dips in two areas. The first is in a narrow zone directly overlying the east-facing escarpment which we interpret as the result of differential compaction above an escarpment. The second area of easterly dips is in a zone that lies in the hanging wall of a gently northwest-dipping normal fault where the east-dipping ash-flow tuff is overlain by moderately to steeply southeast-dipping conglomerate of probable mid-Cenozoic age (Tg). The easterly dips in this zone are interpreted as roll-over in the hanging wall of the normal fault.

Moore (1993) identifies a number of megabreccia zones within Uncle Sam Tuff to the east of the proposed western caldera margin, and several lie well to the south of the Babocomari River. Our mapping shows the southern limit of the megabreccia zones coinciding with the River, and the density of megabreccia zones seems to increase to the north.

The evidence for Lipman and Sawyer's (1985) and Moore's (1993) western caldera margin is not definitive. Given the structural complications, and the fact that there is no constraint on how thick the Uncle Sam Tuff is in the area, it is possible that the entire area lies within the caldera, and that the basal contact throughout the area represents a caldera floor. The increase in the size and abundance of megabreccia zones and their clasts to the north of Babocomari River is similar to the pattern of megabreccia zones in the Tombstone Hills to the east of the San Pedro River. This feature is consistent with the northeast-tilted trap door model suggested for portions of the caldera east of San Pedro River.

Northern margin

The northern caldera margin is constrained only by the limit of exposure. Lipman and Sawyer (1985) and Moore (1993), use the northern limit of Uncle Sam Tuff to identify the northern caldera margin. Shipman and Ferguson (2005) note that porphyry stocks similar to those mapped within the caldera are present in hills lying 6 km northeast of Moore's (1993) northern caldera margin, and they argue that these hills may also lie within the floor of a caldera.

Northeast-tilted trap door caldera?

The only well-defined margin for the source caldera of the Uncle Sam Tuff is to the east. The southern margin is tentatively interpreted as a gently northeast-tilted trap door margin based on two lines of evidence. First, no obvious caldera-related structural boundary has been identified to the south of the southern limit of the caldera fill in the Charleston area. Second, megabreccia zones are absent within the southern caldera fill and increase in size and abundance to the north. The northern margin is essentially undefined and the caldera may extend significantly farther to the north and northwest than previously thought.

Intrusive units and intrusive relationships

The principal intrusive units in the study area are a suite of quartz-feldspar-biotite hypabyssal porphyry sills and stocks that intrude the Uncle Sam Tuff (Krd), and a swarm of northeast-striking coarse-grained andesite porphyry dikes (Kad). Directly to the south, two Upper Cretaceous quartz monzonite stocks (Kgs and Kg) intrude the Bisbee Group (Ks) and the andesite lavas (Ka).

Quartz monzonite of Bronco Hill and the quartz monzonite of Government Draw

Two quartz monzonite stocks herein informally named the quartz monzonite of Bronco Hill and quartz monzonite of Government Draw intrude the andesite volcanics (Ka) directly south of the map area (Pearthree et al., 2005). The quartz monzonite of Bronco Hill has a K/Ar biotite age of 76.30 ± 1.80 Ma (Marvin and Cole, 1978). Despite the fact that this date is nearly 3 million years older than a K/Ar biotite age of 73.5 ± 2.80 Ma (Marvin et al., 1973) for the Uncle Sam Tuff, the stock at Bronco Hill and the Scheffelin Granodiorite (dated at 76.3 ± 3 Ma by Creasy and Kistler (1962)) are both interpreted to be younger than the Uncle Sam Tuff (Lipman and Sawyer, 1985; Moore, 1993). Neither stock is known to intrude the Uncle Sam Tuff. In addition, a clast of medium-grained quartz monzonite similar to the Bronco Hill stock was observed within a rhyolite tuff breccia (Kra) that is overlain by the Uncle Sam Tuff in the northerly adjacent Fairbank map area (Ferguson et al., 2005). Because of this, we believe that one or both of the quartz monzonite of Bronco Hill and the Scheffelin Granodiorite might predate emplacement of the Uncle Sam Tuff. The tuff of Charleston which underlies the Uncle Sam Tuff in the northerly adjacent Fairbank map area (Ferguson et al., 2005) is for the most part a megabreccia unit, and this raises the possibility that the quartz monzonite of Bronco Hill might be related to an older caldera and that the K/Ar dates are not in error.

The quartz monzonite of Government Draw (found only on the Lewis Springs 7.5' map sheet) is differentiated from the stock at Bronco Hill because of slight petrographic differences and because it appears to be correlative with an extensive swarm of northeast-striking coarse-grained andesite porphyry dikes that intrudes all other igneous rocks in the Tombstone Hills - Charleston area including the Scheffelin Granodiorite. None of these dikes intrude the Government Well stock. Of critical importance to this discussion are conflicting reports regarding the cross-cutting relationship between the stock at Bronco Hill (Kg) and the andesite porphyry dikes (Kad). Gilluly (1956) shows a prominent dike of the andesite porphyry intruded by the stock at Bronco Hill, a relationship that would require the stock to postdate all rocks intruded by the andesite porphyry dike swarm (including the Uncle Sam Tuff). This

interpretation may have lead previous workers to conclude that the K/Ar dates of this stock and the Uncle Sam Tuff were in error. The dike in question clearly intrudes the stock, a relationship shown by Newell (1974) and confirmed during our mapping of this critical area.

Coarse-grained andesite porphyry dikes

The coarse-grained andesite porphyry (Kad) forms a swarm of distinctive, northeast-striking dikes and a small stock (along the east edge of the map sheet) that intrudes all other known igneous units in the Tombstone Hills - Charleston area except for the quartz monzonite of Government Draw. The dikes dip steeply to the southeast and intrude a swarm of similarly oriented normal faults in the area. Some of the dikes are composite with granitic interiors and porphyritic margins, and the granitic interiors are petrographically similar to the quartz monzonite of Government Draw. The eastern intrusive contact of the quartz monzonite of Government Draw displays similar relationships with a porphyritic border phase (similar to the andesite porphyry dike unit) intruded by granitic material similar to the rest of the stock. The dikes and the stock are therefore correlated temporally, and since the dikes intrude the Uncle Sam Tuff, the quartz monzonite of Government Draw is interpreted to be the only granitic rock in the area that is known to be older than Uncle Sam Tuff. The dikes and the stock at Government Draw have not been dated.

Structural Geology

Bisbee Group strata in the study area were folded in large wavelength northeast-striking close to open folds. In one area (Lewis Springs map sheet), a weakly developed cleavage appears to be folded by these folds (the cleavage – bedding intersection is folded).

Upper Cretaceous volcanics overlie the folded Bisbee Group with angular unconformity, and are tilted gently to the northeast throughout the area. The northwest tilting is attributed to a set of steeply to moderately southeast-dipping normal faults that cross the study area from southwest to northeast (Figure 1). The fault traces are concealed by alluvium. Two low-lying, southwest-striking horst blocks are the result, one on each side of the San Pedro River. The northwestern horst is overlapped just to the north of the Fairbank map area by a sequence of gently northwest-tilted volcanoclastic conglomerate (Shipman and Ferguson, 2005). The most significant fault is interpreted to lie just to the southeast of the western horst block. Another fault is interpreted to lie just to the southeast of an isolated set of hills along the San Pedro in the center of the Fairbank map area.

A northwest-dipping normal fault is mapped along the crest of the northwestern horst block based on the presence of a strip of steeply to moderately southeast-dipping conglomerate that overlies the Uncle Sam Tuff just north of the Babocomari River. The age relationship between the two oppositely dipping faults and conglomerate sequences and is unknown.

Alteration and mineralization

Alteration in country rock associated with emplacement of the quartz monzonite stocks of Government Well and Bronco Hill in the southerly adjacent Lewis Springs map area (Pearthree et al., 2005) is relatively minor. Rocks older than the Uncle Sam Tuff are pervasively propylitically altered, but show no sign of increased alteration or mineralization adjacent to the granitic stocks. The Uncle Sam Tuff shows little sign of alteration throughout the area. Thin, northeast-striking quartz-sericite-pyrite veinlets with less than 5 cm thick potassic envelopes are present in the stock at Bronco Hill. These are cut by zones of argillic alteration, calcite, and MnO veins associated with northeast-striking faults and the coarse-grained andesite porphyry dike swarm.

Alteration associated with the northeast-striking coarse-grained andesite porphyry dikes is intense and these dikes appear to be the main source of fluid migration and alteration in the Charleston mining district. Wall rocks are typically strongly argillic altered with extensive networks of MnO and quartz-calcite veinlets. At depth, in the Charleston Lead Mine, alteration

associated with these dikes is reported to produce coarse-grained sericitic alteration. Unpublished Anaconda data reported in Reynolds et al. (1986) report a K/Ar sericite age of 76.40 ± 3.0 Ma from a vein in the Charleston Lead Mine. It is worthwhile noting that the Charleston Lead Mine lies at the point where a pair of greater than 10m-thick coarse-grained andesite porphyry dikes intersect the west-facing caldera margin for the tuff of Charleston, and the base of the Uncle Sam Tuff.

An extensive zone of hematite stained, weakly argillic altered rocks to the northeast of the Charleston Lead Mine is directly associated with intrusive contacts between the porphyry of Fairbank and the Uncle Sam Tuff. Alteration effects the intrusive porphyry, but has little effect on the densely welded ash-flow tuff. This zone of alteration strikes northeasterly towards a zone of important mineralized rocks in the Tombstone district that might also be related to this intrusive event.

Recognition that emplacement of medium-grained, phaneritic texture granitic rocks of the Scheffelin Granodiorite, and the quartz monzonite stock at Bronco Hill might be related to volcanic rocks older than the Uncle Sam Tuff raises the possibility that alteration and mineralization in the Charleston district is more complex than previously thought.

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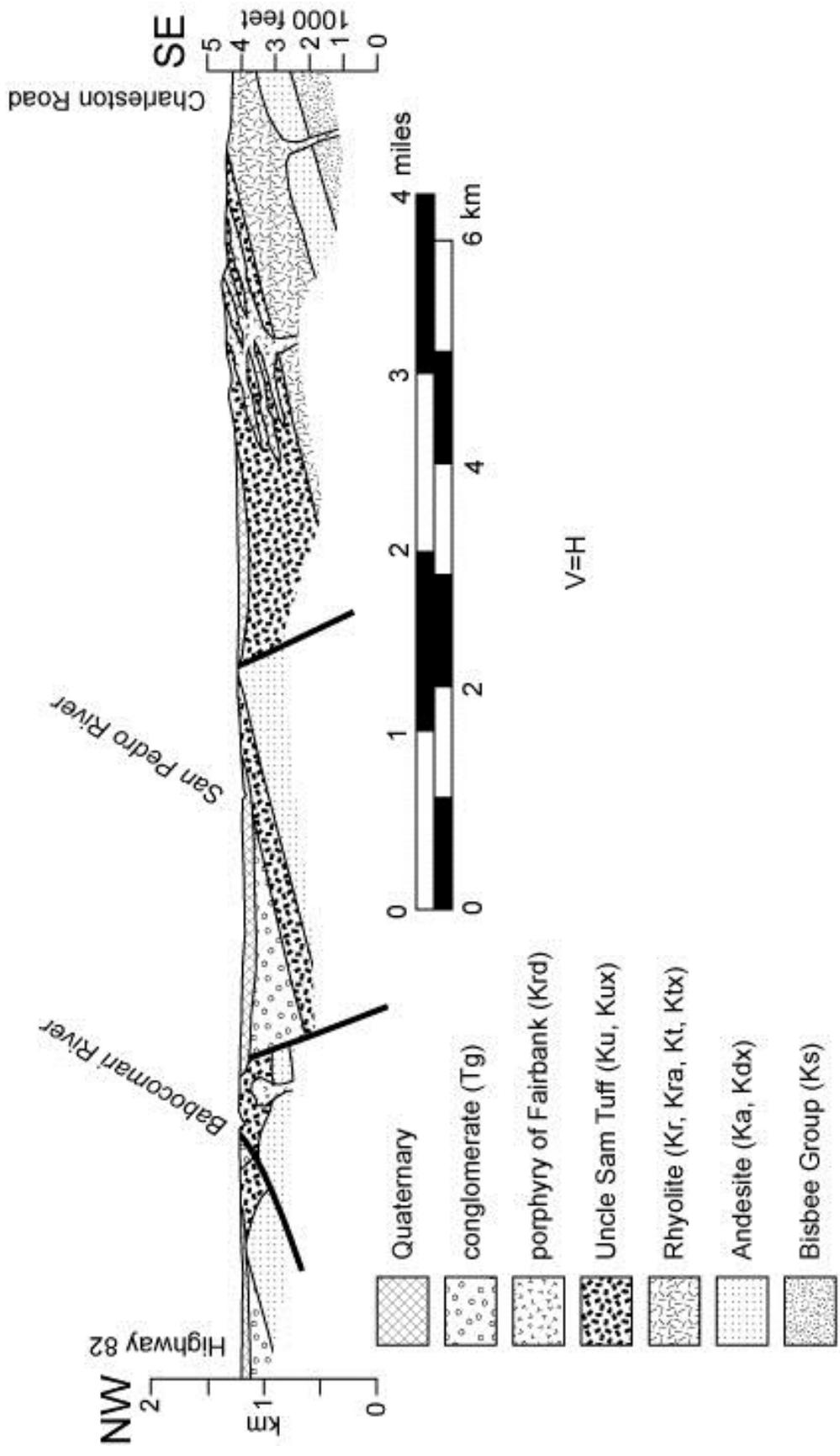


Figure 1 Generalized cross-section across the Fairbank 7.5' quadrangle, Cochise County, Arizona