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THE BENT DOME—PART OF A MAJOR PALEOZOIC UPLIFT IN SOUTHERN NEW MEXICO

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Abstract—The Bent dome is a Proterozoic-cored structural high located in the northern Sacramento Mountains near Bent, New Mexico. The oldest rock units exposed at Bent are Proterozoic(?) altered diorite and diabase at the Virginia copper mine and altered red granite 1.6 km east. Both units are unconformably overlain by a medium-grained, well-sorted, dense quartz sandstone with abundant sedimentary structures, bioturbation and Cambro-Ordovician fish fossils that we interpret as the Bliss Sandstone. In the Virginia mine area the basal Bliss is a distinctive, bright green, glauconite-rich sandstone. In several areas the Bliss is unconformably overlain by a Quaternary red alluvial deposit that looks like Abo Formation but contains Tertiary(?) quartz-eye rhyolite clasts. The Abo Formation does unconformably overlie the Bliss Sandstone in an exposure 1.6 km east of the mine. Copper mineralization along the diorite/sandstone contact appears confined to the Virginia mine area. Prospects to the east along the contact were actually excavated in the green, glauconitic basal Bliss Sandstone. Permian rocks rest directly on Cambro-Ordovician rocks, so this area was an erosional or non-depositional high during late Paleozoic time, most likely as part of the southern prong of the ancestral Rocky Mountain Pedernal uplift. Both Cambro-Ordovician and Permian strata dip away from the core of the dome, indicating that doming continued well into Permian time.

INTRODUCTION

The Bent dome (Bachman, 1960) is a Precambrian-cored structural high located in Otero County near Bent, New Mexico (Fig. 1), about 19 km northeast of Tularosa (secs. 25 and 26, T13S, R11E and secs. 30 and 31, T13S, R12E). The area is noteworthy for several reasons. The Virginia mine (inactive), situated on the dome, contains an estimated 800,000 tons of 2.5% copper ore reserves. The age of the crystalline host rock (diorite) at the mine is unknown (estimates range from Precambrian to Tertiary), as is the source and extent of the copper mineralization. There are similar questions concerning the age of the sandstone that unconformably overlies the diorite, and the nature of the contact between the sandstone and overlying red beds. These stratigraphic data are important because the Bent dome has been described as the southernmost basement exposure of the Pedernal landmass of the ancestral Rocky Mountains (Bachman, 1960), and is therefore a key in understanding the distribution of Paleozoic strata and structures.

The purposes of this paper are to summarize previous work in the area, and to present new data and interpretations of stratigraphy and structure based on detailed mapping and petrography. The final section of the paper contains some speculations on Paleozoic tectonics that are based on these new data.

PREVIOUS WORK

When L. C. Graton visited the area in 1905 (Lindgren et al., 1910), development of the Virginia mine had only recently begun, and geologic relationships were poorly exposed and understood. A mineralized diorite porphyry of unknown age appeared to intrude, and arch up, overlying white sandstones and red beds. Graton noted two types of copper mineralization: (1) disseminated in sandstone; and (2) veins in diorite and limestone. He concluded that hot, alkaline, carbonate solutions containing Cu and Fe sulfides ascended to form a mineralized zone near the top of the diorite.

Ball (1913) published a detailed study of the copper deposits at Bent. He suggested that the oldest rock in the area is a light-gray quartzite which crops out 1.6 km east of the mine (sec. 26), and was encountered at the bottom of several drill holes in the vicinity of the mine. He also stated that in one poor exposure the diorite appeared intrusive into the quartzite, suggesting that the diorite is Precambrian, and that the overlying white sandstone is probably Carboniferous, unconformably overlain by "red beds." For genesis of the ore, Ball (1913) concluded that the Precambrian diorite, which was intruded into some rock that has since been eroded, was mineralized by magmatic waters that deposited chalcocite and other minerals. The diorite was exposed in the Paleozoic, whereupon copper minerals were concentrated along the base of the sandstone. During a time of Tertiary faulting, secondary mineralization occurred in the diorite and sandstone.

In a reconnaissance study, Bachman (1954) mapped two small exposures of Precambrian rock to the east of the mine, mainly in sec. 25. However, he thought that the diorite near the mine was Tertiary, and that the overlying sandstone was Pennsylvanian(?). Foster (1959) stated that the diorite might be Precambrian rather than Tertiary, and that it does not arch up the overlying sediments. Instead, post-intrusive faulting cuts both the diorite and the Pennsylvanian(?) sandstone and localized mineralization.

When Bachman (1960) remapped the area in more detail, he named the regional basement high the Bent dome. He conceded that the diorite might be Precambrian, but that it resembled nearby Tertiary diorites. The Pennsylvanian(?) sandstone thins eastward so that it is absent on the east side of the dome where other Precambrian rocks crop out. In sec. 25, these Precambrian rocks consist of a large exposure of light-gray quartzite that appears to be intruded by coarsely crystalline granite.

Denison and Hetherington (1969) examined the quartzite and granite in sec. 25. They found that the quartzite nearly lacks lithic fragments and feldspar grains, contains no metamorphic minerals, lacks shearing, and is probably equivalent to the Llanoria Formation of the Franklin Mountains. The granite, which may intrude the quartzite, is too altered to date, but may be part of the 950 Ma igneous event found to the south.

Foord and Moore (1991) mapped and sampled rocks in the Virginia mine area. They concluded that the diorite was Precambrian, the sand-

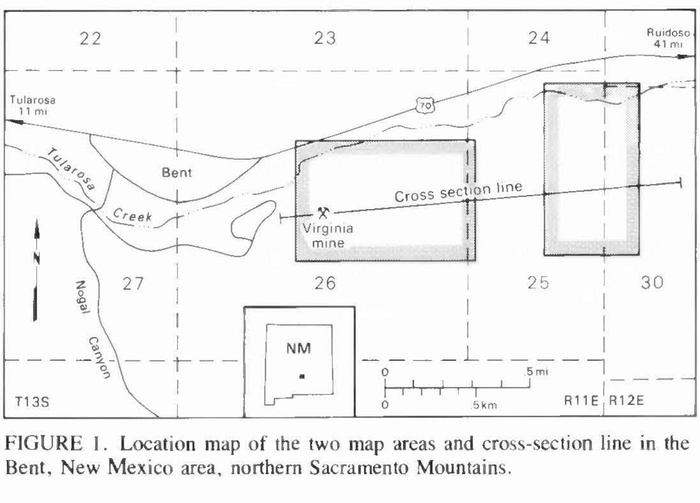


FIGURE 1. Location map of the two map areas and cross-section line in the Bent, New Mexico area, northern Sacramento Mountains.

stone was Bliss Sandstone, and no Abo Formation was exposed in the mine area. Their history of mineralization was very similar to that proposed by Ball (1913).

ROCK TYPES

Our investigation of Bent dome consisted of detailed mapping (scale 1:3000) and sample collection within two areas of bedrock exposure (Fig. 1). Our interpretations of rock-unit correlations and designations are based on this mapping, thin-section analysis, mapping and petrography of Bliss Sandstone and underlying rocks along the Sacramento escarpment, and regional relationships. In the lithologic discussion section below, we evaluate rocks and contacts within three critical areas of exposure, and discuss all Quaternary units separately at the end of the section.

Virginia mine area

Diorite (Proterozoic?)

In the Virginia mine, and along the canyon east of the mine, exposures of igneous rock exhibit a variety of textures and mineralogies (Fig. 2). Most of the unit is a dark gray to greenish to black, medium-grained porphyry composed of highly altered feldspar and Fe-Mg minerals. Contact and crosscutting relations among the various phases within the intrusive body are unknown. No foliation is visible. According to Jacques Renault of the New Mexico Bureau of Mines and Mineral Resources (personal comm., 1991), of the four thin sections studied, three are diabases and one is a diorite. All of the rocks are highly altered; most Fe-Mg minerals (hornblende, augite and biotite) are partially or totally altered to some combination of chlorite, clay and sericite. Magnetite is the most abundant opaque phase. None of the samples contain quartz crystals, although three display myrmekitic textures with altered alkali feldspar interstitial to plagioclase laths. One sample, from the quarry face of the mine, was probably a hypabyssal intrusion.

Where the contact between diorite and overlying sandstone is exposed, the boundary is a sharp, even surface. At the Virginia mine area, the upper 6 m or so of diorite is highly altered. We interpret the contact as an unconformity, with at least some of the alteration due to weathering on an eroded diorite surface. The diorite is therefore older than the overlying sedimentary rocks, which we believe are Cambro-Ordovician. Elsewhere in southern New Mexico, Cambro-Ordovician strata are typically underlain by Proterozoic rocks; we believe that this is also true in the Bent area.

Bliss Sandstone (Cambro-Ordovician)

At the Virginia mine, a well-indurated, generally well-sorted, fine- to coarse-grained quartz sandstone unconformably overlies the diorite. This unit is estimated to be about 30+ m thick in the mine area. Dips are gentle, from about 15° northward along the highway, to about 20° westward at the mine. Two general sandstone types are exposed, a basal, bright olive-green, glauconite-rich sandstone, and an overlying, light-gray-to-brown sandstone with local carbonate sandstone horizons.

The basal green sandstone is several meters thick, and can be traced discontinuously for about 1.5 km eastward, where it is covered by Tertiary alluvium. Numerous prospect pits define its trend. The rock typically contains thin, alternating white and green layers. In thin section, the white layers are carbonate-rich whereas the green layers are glauconite-rich. Quartz grains, which compose 15–50% of the rock, are subangular to subrounded, are mantled by quartz overgrowths, and exhibit minor undulose extinction and embayments. Most quartz grains are separated by euhedral dolomite rhombs that form up to 65% of the rock in the white layers.

Glauconite is bright green with a distinctive fine-grained sugary texture and rounded pelletoid form. It is generally agreed that glauconite forms by marine diagenesis in shallow water during periods of slow sedimentation under moderately reducing conditions (Deer et al., 1966). A dark brown to opaque, euhedral, rectangular mineral, probably siderite (P. Mozley, personal comm., 1991), occurs throughout the rock, and appears to have replaced carbonate. Minor amounts of small to large, subrounded grains of chert are also common. No fragments of diorite or detrital feldspar grains have been observed in samples of the basal sandstone. One other noteworthy constituent of the basal green sandstone is prominent fragments of light-colored, prismatic, non-birefringent phosphatic material that are aligned with the layering (Fig. 3). This material was recognized as fossilized fish fragments by P. Mozley and D. Johnson of New Mexico Institute of Mining and Technology. A vertebrate paleontologist, J. Zidek (New Mexico Bureau of Mines and Mineral Resources), then identified them as tesserae of Heterostraci (i.e., scales of a jawless vertebrate). These animals lived in late Cambrian to Devonian time.

Two samples of mineralized, glauconitic sandstone from the Virginia mine assayed at 0.70% and 0.98% Cu. Neither sample contained detected concentrations of Au or Ag.

Above the green sandstone is a sequence of light-colored, generally medium-grained sandstone with local horizons of well-developed cross laminations and intense bioturbation. In thin section, the sandstone consists of an interlocking mosaic of typically subround to round quartz grains, with authigenic quartz overgrowths (Fig. 4). Quartz grains generally contain 120° triple-junction boundaries, some undulose extinction, and minor evidence of recrystallization from serrate boundaries and local subgrains. Minor carbonate cement occurs between quartz grains.

We interpret this sandstone as the Cambro-Ordovician Bliss Sandstone. Its appearance is similar to the Bliss exposed 50 km to the south in the Sacramento escarpment (Pray, 1961). Both units are medium-grained, siliceous, cross-laminated, bioturbated, and locally include glauconitic quartz sandstone with minor interbeds of dolomitic sandstone. Pray (1961) also noted the presence of chert grains and rare fossils in the basal Bliss, and a thickness of 34 m (110 ft) for the unit; all consistent with the sandstone at Bent. In addition, both sandstone units rest unconformably above basement rocks thought to be Proterozoic in age.

Several previous workers (Ball, 1913; Foster, 1959; Bachman, 1954, 1960) considered this sandstone to be Pennsylvanian. Of the three Pennsylvanian formations in the Sacramento Mountains (Gobbler, Beeman and Holder) only the Gobbler Formation contains appreciable thicknesses of well-sorted quartz sandstones. However, these strata typically contain angular, very coarse-grained quartz grains (Pray, 1961); quite different from the rocks at Bent. Furthermore, neither glauconite nor strong bioturbation are reported from the lower Pennsylvanian units, and the limestones, shales, feldspathic sandstones and cherty limestones characteristic of the Pennsylvanian are not present at Bent. The only other unit which the sandstone could conceivably represent is the lower Permian Laborcita Formation. Although the Laborcita does contain quartz sandstone horizons, thicknesses are minor, and the unit is dominated by calcareous shales and argillaceous limestones (Otte, 1959; Pray, 1961).

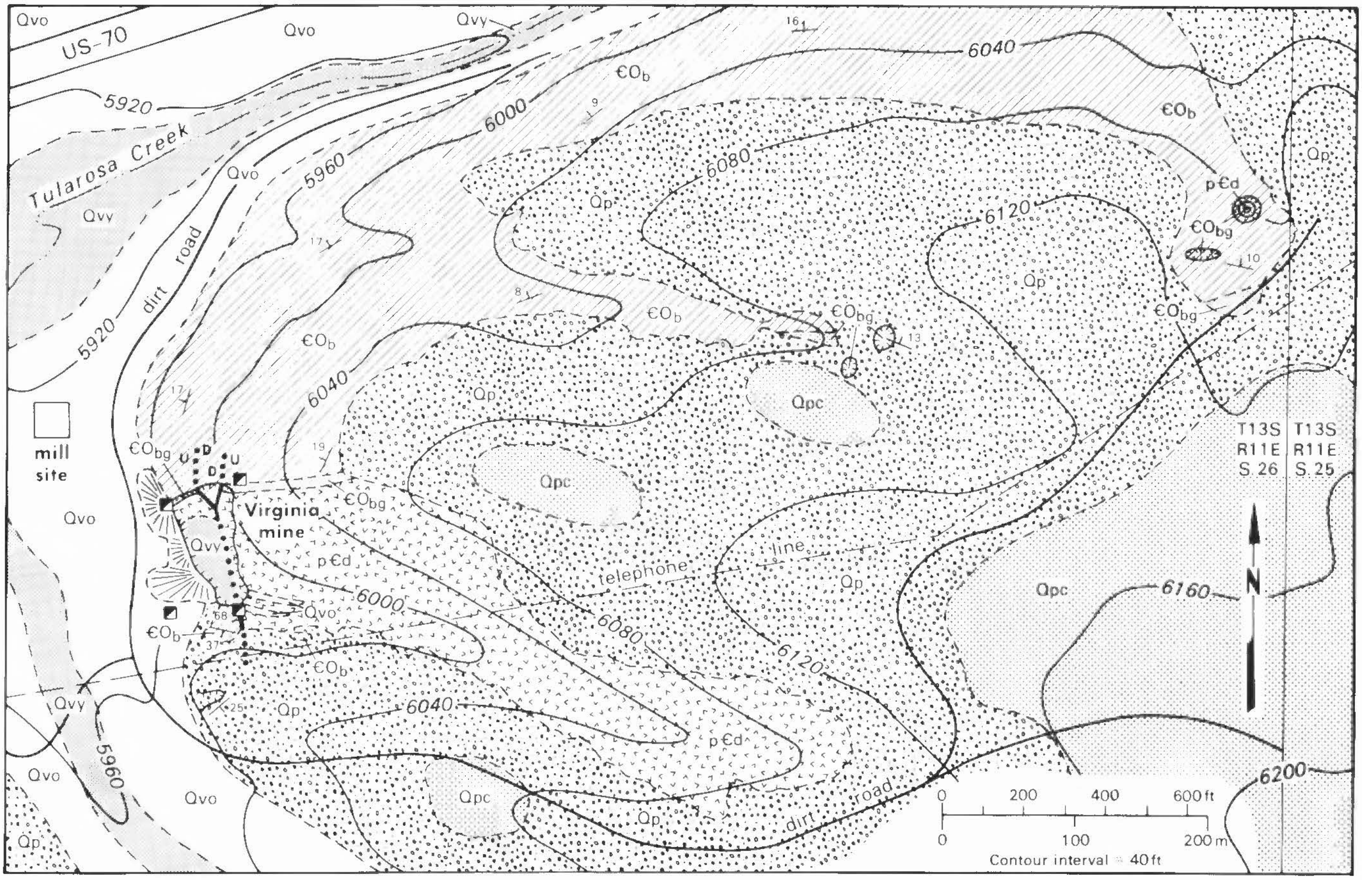
It is also worth noting that several old mining reports of the Virginia mine stated that diamond drill holes in the mine area encountered quartzite beneath the diorite body. Wilson (1921) reported that this quartzite was penetrated at 122 m (400 ft) depth in the mine area, and at 40 m (135 ft) depth about 450 m (1500 ft) east of the mine. None of the drill records are now available. Assuming that the diorite is Proterozoic, perhaps this underlying quartzite is part of the supracrustal succession into which the diorite was intruded. Alternatively, if the diorite is not Proterozoic, the underlying quartzite might be Paleozoic, perhaps even Bliss Sandstone.

Exposures 1.6 km east of the Virginia mine

Bedrock outcrops also exist in two drainages about 1.6 km east of the mine, where igneous basement rock is unconformably overlain by Bliss Sandstone (Fig. 5). These exposures contain stratigraphic relationships similar to those near the mine, with the addition of outcrops of the Abo Formation.

Granite (Proterozoic?)

A brick-red, highly weathered, coarse-grained granitic rock is ex-



Surficial Deposits

Qvy— Young valley-fill alluvium; includes active channel and floodplain deposits. Consists mainly of unconsolidated, fine to coarse sand, silt, and clay with gravel lenses.

Qvo— Older valley-fill alluvium; includes terrace deposits associated with incision and backfilling of valley. Consists of weakly consolidated, poorly to moderately stratified, fine to coarse sand, silt, and clay with gravel lenses.

Qcb— Bliss colluvial deposit; contains mainly Bliss Ss. clast-rich colluvium in eastern map area.

Qpc— Piedmont-slope deposit with carbonate clasts; mainly buff to light brown, poorly sorted, weakly to moderately consolidated silty sand to conglomeratic sands. Subangular to subrounded clasts included. Overlies Qp.

Qp— Piedmont-slope deposit; reddish brown, poorly sorted, moderately consolidated silt, sand, and conglomerate of reworked Precambrian rock, Paleozoic sedimentary rock, and Tertiary rhyolite(?). Clasts are angular to subrounded and up to small boulder size.

Abo Formation

Pa— Dark red to reddish brown, thin- to medium-bedded, shale and siltstone with sandstone interbeds.

Pab— In eastern map, lowermost Abo Fm. consisting of rounded Bliss sandstone lag deposit.

Bliss Sandstone

€O_b— White to tan to brown, generally well-sorted, calcareous sandstone with local cross-laminations, bioturbations, and limey lenses.

€O_{bc}— Crystalline, pink to purple, resistant Bliss Ss. Qcb is formed dominantly of €O_{bc}.

€O_{bb}—In eastern map, basal Bliss Ss. above p€g.

€O_{bg}—In western map, basal, green, glauconite-rich Bliss Ss., above p€d.

Proterozoic (?)

p€d— Various types of black to gray to green, medium-grained dioritic rock, probably Proterozoic. Upper part is mineralized at Virginia copper mine. All samples are altered.

p€g— Brick-red, medium- to coarse-grained granitic rock, probably Proterozoic. All exposures are highly weathered and altered.

FIGURE 2. Geologic map of the Virginia mine area, just east of Bent, New Mexico. See Fig. 1 for location of map area.

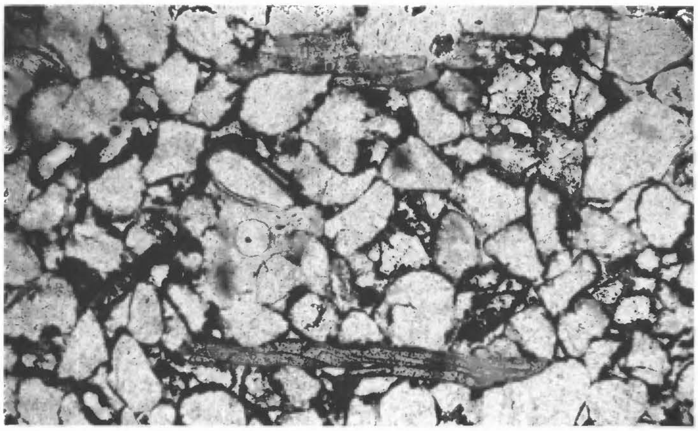


FIGURE 3. Plane light photomicrograph of basal Bliss Sandstone from the Virginia mine. Field of view is 2.5 mm. The long, prismatic fragments are tesserae of Heterostraci (scales of a jawless invertebrate "fish"). Other grains are dominantly quartz, dolomite and glauconite.

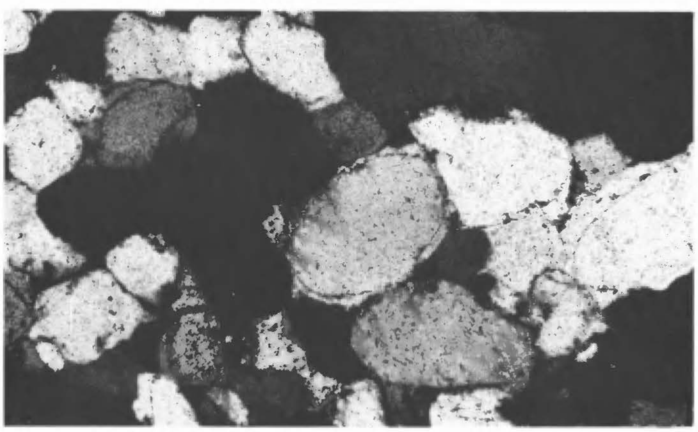


FIGURE 4. Plane light photomicrograph of white, well-sorted quartzitic sandstone from Bliss Formation, north of Virginia mine. Note authigenic quartz overgrowths rimming round quartz grain in center of photo. Field of view is 2.5 mm.

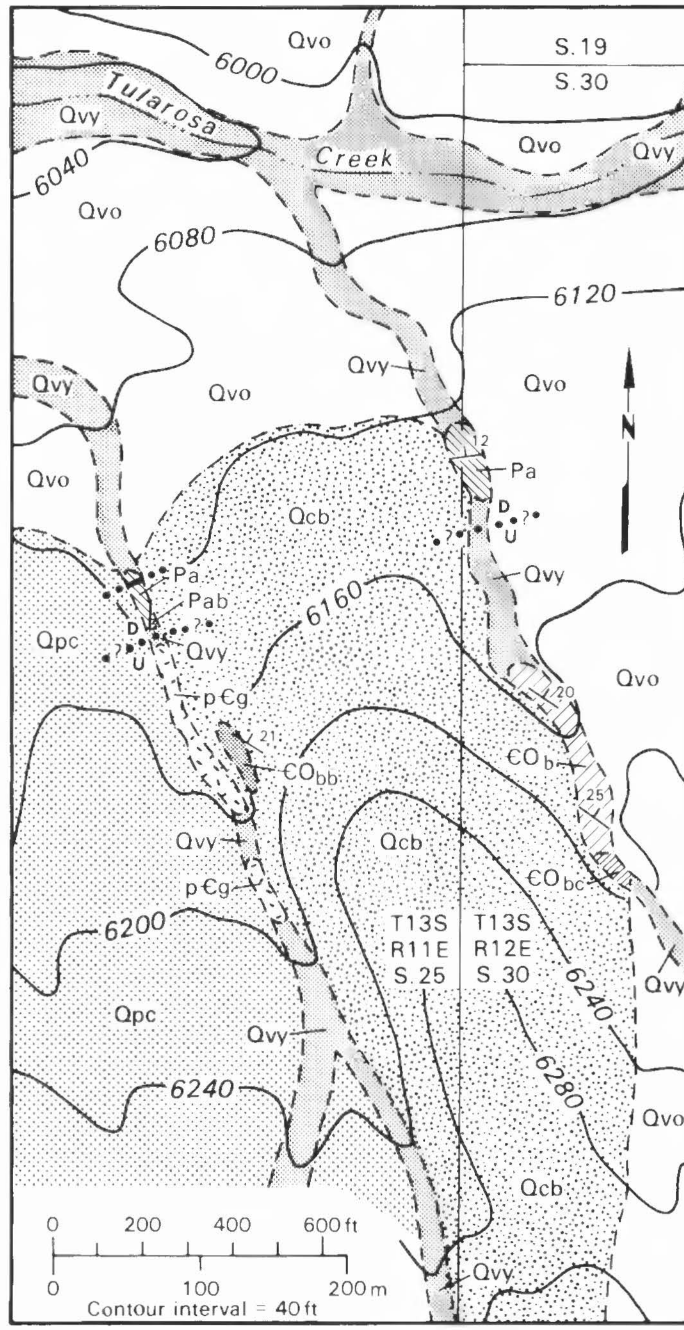


FIGURE 5. Geologic map of the eastern map area, 1.6 km east of the Virginia mine. See Fig. 2 for explanation of map units, and Fig. 1 for location of map area.

posed in the western drainage of the eastern map area. In thin section, the rock contains about 20% altered, euhedral feldspar phenocrysts up to 5 mm across. The groundmass consists of about 65% altered feldspar (0.5–0.6 mm), 25% quartz, 5% biotite altered mainly to chlorite, and 5% opaque minerals, with accessory zircon (Fig. 6). Although sericitic alteration of feldspar is well developed, relict feldspar textures indicate that the rock contains more alkali feldspar than plagioclase, and we therefore call the rock a granite.

Although the granite/sandstone contact is covered with colluvium, field relations suggest that the contact is unconformable rather than intrusive. The contact is straight, and the lowermost sandstone contains coarse clasts of altered red granite and well-rounded vein quartz clasts up to 2 cm in diameter. No granitic or pegmatitic veins or apophyses are found in the sandstone, and no contact metamorphic zone exists.

Bliss Sandstone

The medium-grained quartz sandstone exposed in the eastern map area is similar to that of the Virginia mine area. The rock is well layered and locally contains planar crossbeds and ripple marks (Fig. 7). In thin section, about 98% of the rock consists of an interlocking mosaic of quartz grains that generally lack overgrowth rims, show undulose extinction, and bound one another along 120° triple junctions. The remainder of the rock is composed of small altered feldspar(?) grains and carbonate cement.

Within the eastern Bliss Sandstone is a horizon of resistant, pink to purple, quartzitic sandstone that underlies a dip slope. This rock is petrographically identical to quartzitic clasts common in a Quaternary alluvial deposit to the west. It consists of a moderately well sorted, subrounded, interlocking mosaic of quartz grains that display undulose extinction and 120° equilibrium boundaries. Minor amounts of chert and altered feldspar are also present.

This horizon of quartzitic sandstone is probably the unit that was referred to as Precambrian quartzite by previous workers. The rock is moderately well recrystallized and is similar to some Proterozoic quartzites in central New Mexico, but clearly rests within the Bliss Sandstone.

Abo Formation (Permian)

The Abo Formation is exposed along the bottoms of drainages in two areas (Fig. 5), northwesternmost sec. 30, T13S, R12E, and northeast sec. 25, T13S, R11E. The small exposure in sec. 30 is an isolated

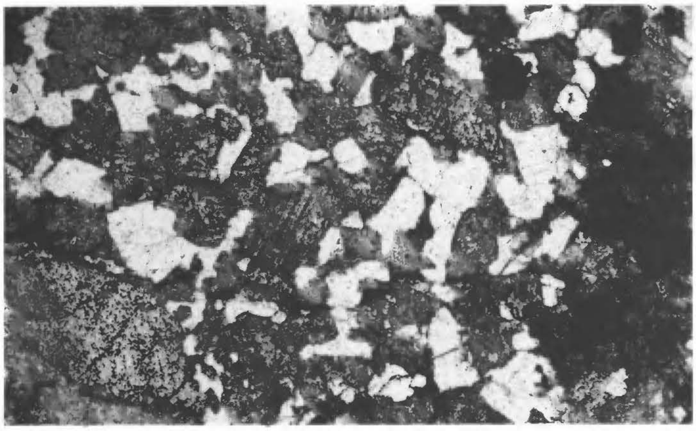


FIGURE 6. Plane light photomicrograph of granite from eastern map area. Rock consists of equigranular matrix of feldspar (mottled grains), quartz (clear grains), opaque minerals and biotite partially altered to chlorite (dark grains on right). Relict twinned feldspar can be seen in grain near center of photo, and part of large feldspar in lower left corner. Field of view is 2.5 mm.

FIGURE 7. Ripples on gently dipping bedding planes in Bliss Sandstone, eastern map area.

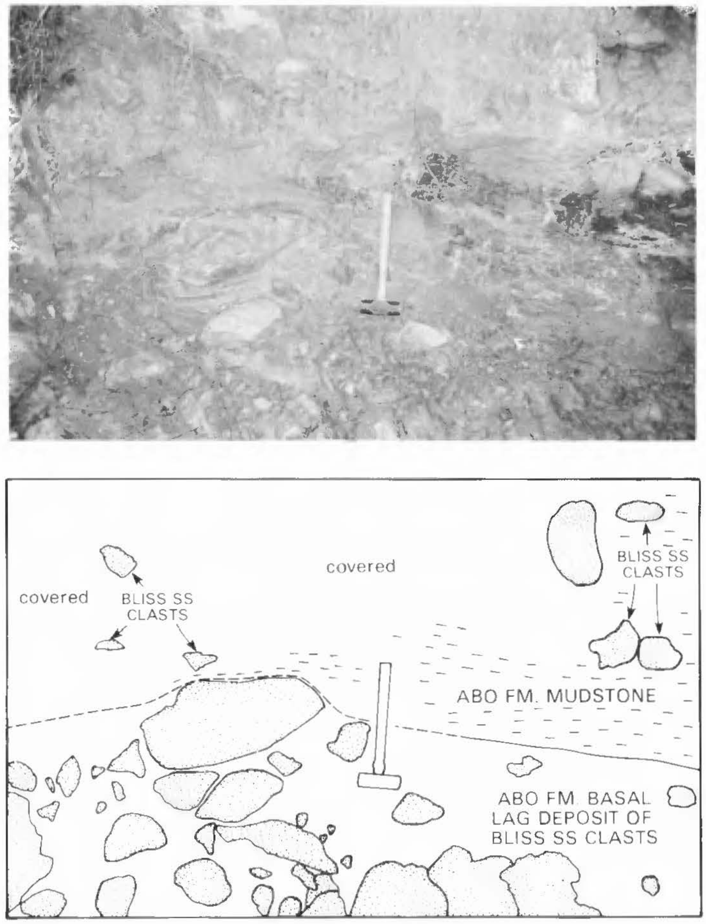


FIGURE 8. Photo and sketch of contact between lowermost Abo Formation, which consists of conglomeratic crystalline Bliss Sandstone clasts (lag deposit), and overlying Abo Formation mudstones, in eastern map area. Note that crystalline sandstone boulders and cobbles are incorporated into mudstone.

outcrop of gently northeast-dipping red sandstones and mudstones. However, exposed in sec. 25, the lowermost Abo Formation consists of a clast-supported conglomerate with large (up to 30 cm) subrounded cobbles and boulders of Bliss Sandstone. This rock is most likely a lag deposit on top of the eroded Bliss. Atop the conglomerate is mudstone that contains quartzitic sandstone clasts, up to 15 cm in diameter (Fig. 8). These clasts indicate that this is a depositional contact.

This outcrop is about 20 m along strike from the basal Bliss Sandstone to the south. Therefore, we separate the two exposures with a down-to-the-north high-angle fault. A series of parallel fractures, most likely related to this fault, which cut the lag deposit, suggest that this fault dips steeply north.

North of Virginia mine along US-70

Bliss Sandstone

The white to brown quartz sandstone unit with dolomitic interbeds, exposed in the large roadcut just north of the Virginia mine, is similar in morphology and orientation to the Bliss Sandstone in the mine area. Unless a major east-striking fault lies buried beneath Tularosa Creek, these two sandstones are most likely equivalent and continuous.

Surficial deposits

Piedmont-slope deposits (Qp and Qpc)

Unconformably capping ridgetops are moderately consolidated piedmont-slope deposits that accumulated on a generally west-dipping erosional surface that at one time extended over the area. Two subunits are recognized: (1) Qp, a lower deposit consisting of a conglomeratic basal unit and overlying reddish-brown silty sand containing abundant subangular to subrounded clasts of pink to purple sandstone/quartzite, limestone, rhyolite porphyry, and brick-red granitic rock; and (2) Qpc, an upper buff to light gray, silty sand containing mainly subangular to subrounded clasts of limestone. Although the ages of the two subunits are unknown, they could be as old as 1 to 2 Ma.

Qp crops out in several areas. About 50 m south of the Virginia mine is a prospect exposure of bedded red mudstone and red conglomerate. The conglomerate is well cemented, poorly sorted, matrix-supported, with subangular to subrounded, pebble- to cobble-size clasts of quartz-eye rhyolite porphyry, granitic rock and crystalline sandstone. In several places along the north side of the highway, a similar deposit unconformably overlies the Bliss Sandstone. These units have been called Abo Formation by some previous workers (Bachman, 1960). This is understandable, as they are well bedded and most of the matrix appears to be derived from red beds. However, we suspect that the quartz-eye rhyolite clasts are Tertiary in age, and therefore the unit must be Tertiary or Quaternary.

Bliss colluvial deposit (Qcb)

This unit is found only in the eastern map area where it blankets a dip slope of Bliss Sandstone. It consists of very resistant, pink to purple, vitreous, somewhat recrystallized clasts of sandstone/quartzite that are derived from the underlying Bliss Sandstone.

Old valley fill alluvium (Qvo)

This unit includes terrace deposits associated with incision and partial backfilling of the valley. At least two terrace levels exist up to 10 m above the present base level. The alluvium consists of weakly consolidated sand, silt and clay with coarse gravel lenses. Bedding is generally weak with locally well defined channels. These deposits represent channel, overbank and debris-flow deposition.

STRUCTURE

A pair of graben-forming conjugate normal faults is exposed in the quarry face of the Virginia mine (Fig. 9). These faults dip about 45° and 65°, east and west, respectively, and have resulted in a wedge-shaped block of sandstone within the diorite. Copper mineralization has been concentrated along the brecciated fault zones. Age of faulting is unknown and can only be bracketed between Cambro-Ordovician and Quaternary.

In the eastern map area, a high-angle, north-dipping normal fault has been inferred between exposures of Abo Formation and older rocks. This structure does not cut Quaternary units, and thus developed sometime between Permian and Quaternary times.

The overall structure of Phanerozoic rocks in the Bent area is that of a broad dome. At the Virginia mine, sandstones dip west; north of the mine, sandstones dip north; 1.6 km east of the mine, sandstones (and Abo Formation) dip northeast to east (Fig. 10). Bachman (1960, fig. 108.1) showed that south and southeast of the mine, rocks dip southwest to southeast. These dips also appear to reflect the orientation of the unconformable surface below the sandstone, and to a lesser extent bedding in Permian and some younger rocks that encircle the mine area.

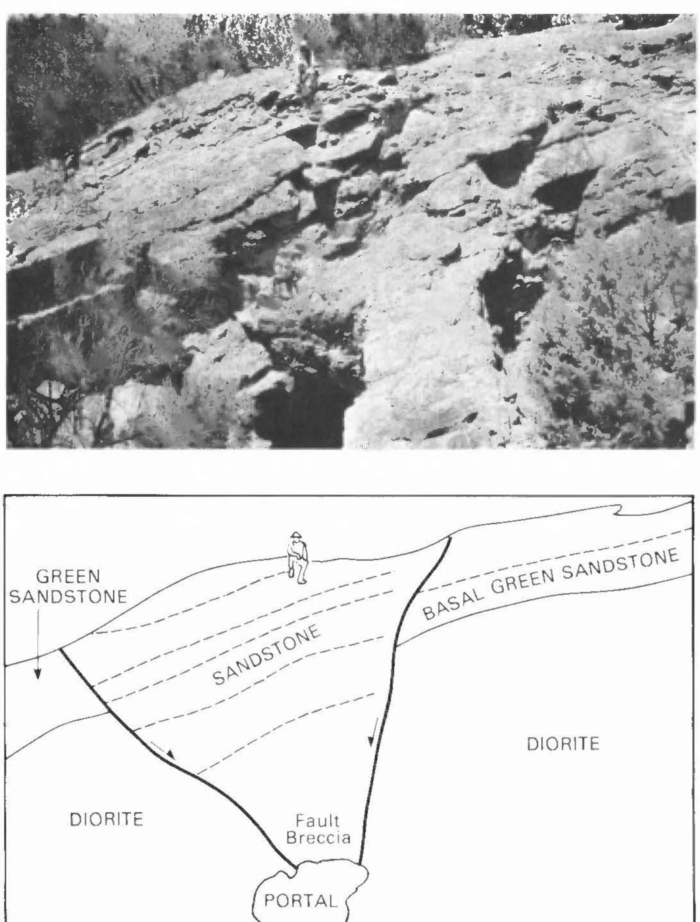


FIGURE 9. Photo and sketch of quarry face at Virginia mine. East- and west-dipping fault have downdropped a wedge of Bliss Sandstone into mineralized diorite. Basal, green Bliss Sandstone is exposed on both sides of graben. The highest grade copper ore exists along the line of intersection of the two faults, where the portal is excavated.

The Abo Formation appears to thicken dramatically away from the dome area. Bachman (1960) measured thicknesses of Abo Formation of about 30 m (100 ft) just east of the eastern map area and 67 m (220 ft) on the southeast flank of the dome in sec. 36. However, 10 km to the west, the Abo Formation is 427 m (1400 ft) thick, and rests on Late Pennsylvanian and Early Permian strata (Pray, 1959).

It appears then, that the Bent dome has been a long-lived structural/topographic feature. The area was an erosional or non-depositional high prior to Permian time, and doming continued subsequent to deposition of the Abo Formation. This is consistent with the findings of Pray (1952), who has shown that the Abo Formation in the central Sacramento Mountains was at least in part contemporaneous with deformation. In most of the Sacramento Mountains to the south, the Abo Formation rests with angular unconformity on Pennsylvanian rocks. This angular discordance is as much as 60° in the central and southern parts of the range (Pray, 1961).

CONCLUSIONS

1. The two oldest exposed rock units in the Bent area are diorite and diabase at the Virginia mine, and red granite 1.6 km (1 mi) east. Both units are probably Proterozoic in age. Relative ages are unknown. Neither unit displays evidence of ductile deformation. Both are highly altered, in part because all exposures are just below a major unconformity.

2. Potentially, the oldest rock unit described at Bent is quartzite, reportedly encountered below the diorite in several drill holes near the Virginia mine. Contact relations with the diorite are unknown.

3. Bliss Sandstone unconformably overlies both the diorite at the mine and the quartz monzonite 1.6 km to the east. The Bliss is a medium-grained, well-sorted quartz sandstone with a local distinctive, green, basal, glauconitic layer containing Cambro-Ordovician "fish" fossils, and abundant sedimentary structures and worm burrows.

4. The Abo Formation does not visibly overlie the Bliss Sandstone near the mine or across NM-70 in the roadcut to the north. The red sedimentary unit with basal conglomerate that does overlie the Bliss in these areas is a Quaternary alluvial deposit. The Abo Formation does unconformably overlie the Bliss Sandstone in an exposure 1.6 km to the east of the mine.

5. Quartz-eye rhyolite porphyry clasts found in the red conglomerate, previously ascribed to the Precambrian, are thought to be Tertiary. They are found in red Quaternary alluvial deposits, not in the Abo Formation.

6. Copper mineralization is confined to the Virginia mine area. Prospects to the east along the Bliss/diorite contact were actually excavated in the green, glauconite-rich, basal Bliss Sandstone.

7. The Bent dome is a structural high that exposes probable Proterozoic rocks in its core. Permian rocks rest directly on Cambro-Ordovician rocks, so this area was an erosional or non-depositional high during late Paleozoic time, most likely as part of the southern prong of the ancestral Rocky Mountain Pedernal uplift. Both Cambro-Ordovician and Permian rocks dip away from the core of the dome, indicating that doming continued well into Permian time. The nature of the structures that bound this uplift are unknown, but major faults and folds of various ages exist nearby in the Sacramento Mountains.

ACKNOWLEDGMENTS

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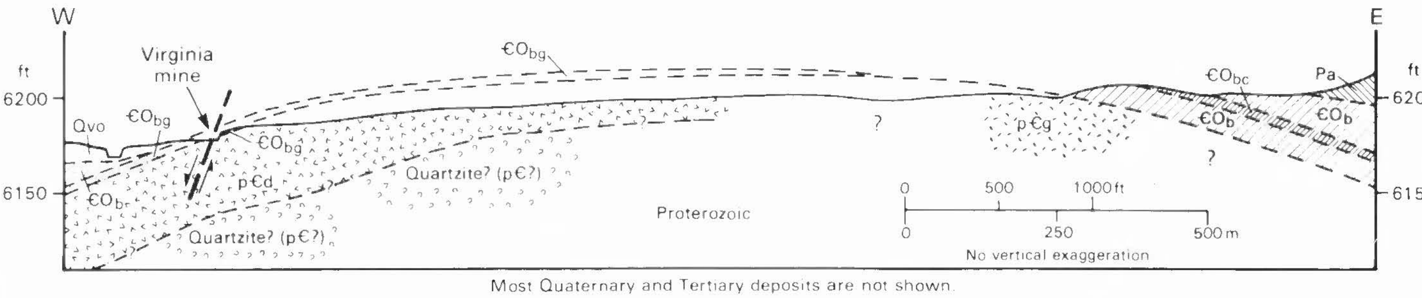

FIGURE 10. Cross section through the Bent dome. See Fig. 1 for location of cross-section line. Dips on western and eastern edges of cross section are based on field measurements. Bliss-basement rock contact in air is based on dip measurements from the north, projected onto plane of cross section. Existence of quartzite(?) unit underlying diorite is based on old mining reports of drill-hole data in two areas along section line.

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Two manly Bureau geologists doing battlefield geology near Bent Dome. Paul Bauer (l) and Rick Lozinsky try to decide who will lead the operation. Check out the senior authorship on their paper to find out who took charge.

The train depot at Cloudcroft near the turn of the century. Think of arriving here during July after leaving the heat and monsoon humidity of El Paso! From the Alfred J. Black Collection. Black was an engineer on the line around the turn of the century; he collected photographs but was not the photographer. Courtesy of Spencer Wilson.