Text to accompany NBMG Map 104

TERTIARY GEOLOGY OF THE REVEILLE QUADRANGLE, NYE COUNTY, NEVADA

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ABSTRACT

The Reveille Quadrangle has had a protracted history of Tertiary volcanism. Volcanic units range in composition from basalt to rhyolite and in age from Oligocene(?) to Pliocene. In their mapping (1:48,000) of the southern Pancake Range and northern Reveille Range, Ekren and others (1973) interpreted many contacts between Tertiary rocks in the northern Reveille Range as faults associated with inferred strike-slip deformation between 26 and 18.5 Ma. More detailed mapping, unit characteristics, and lithologic contact relations discussed here for the Reveille Quadrangle suggest that topography associated with two calderas is a more plausible interpretation of the exposed geology and that strike-slip faulting had little or no influence in this area. Volcanic activity culminated with two episodes of isotopically distinct basaltic volcanism (6 and 3 Ma) that were separated by a more evolved intermediate phase associated with two trachytic to tristanite domes. Pliocene basaltic volcanism appears to have occurred during or after uplift associated with range-bounding normal faults in the Reveille Range.

LIMITED FIELD EVIDENCE FOR STRIKE-SLIP DEFORMATION

Ekren and others (1973) mapped most contacts between Tertiary volcanic rocks and between Tertiary rocks and Paleozoic rocks in the Reveille Range as a combination of strike-slip, high-angle normal, and low-angle thrust or gravity slide faults. In contrast, we interpret most contacts to be depositional, in many cases reflecting significant paleotopography. Much of the paleotopography is related to the margins of two calderas.

Ekren and others (1973) interpreted a "period of intense strike-slip faulting in the Reveille Range and adjacent areas between 18.5 and 26 m.y. ago." Regionally, these faults include north- to northwest-striking, high-angle, sinistral strike-slip faults along the northern and eastern half of the range, a series of thrust faults and landslide breccias that are spatially and temporally related to the strike-slip faults, and dextral strike-slip faults in the southern Pancake Range. However, Ekren and others (1973) apparently contradict themselves by saying that this faulting occurred between 18 and 26 Ma, but show these faults cutting Pliocene basalt.

Ekren and others (1973) mapped a zone about 14 km long of splaying and anastomosing sinistral strike-slip faults through the central part of the northern Reveille Range. From north to south in the Reveille Quadrangle, this fault system and kinematically related thrust faults affect nearly the entire Tertiary volcanic section including Pliocene basalts (see Ekren and others, 1973). For example, one of the main strike-slip faults of this system was mapped as the contact that juxtaposes the tuff of Goblin Knobs and Windous Butte Formation(?) in the south-central part of the quadrangle (4208.000N, 572.500 E). This contact is nowhere exposed, although in places topography and the attitudes of compaction foliation in both units define a moderately to steeply dipping contact. We found no conclusive field evidence for a fault along this contact, and as discussed below, we interpret this contact as the caldera margin for the tuff of Goblin Knobs. Most of the strike-slip and thrust faults mapped by Ekren and others (1973), both within the Reveille Quadrangle and farther north, could not be recognized because of either lack of exposure or field evidence. Field observations made during our study suggest alternative interpretations for contacts previously mapped as strike-slip or thrust faults by Ekren and others (1973). We conclude that strike-slip faults and kinematically associated structures mapped by these authors are absent or have little importance in the Tertiary structural development of the Reveille Range.

STRATIGRAPHIC EVIDENCE FOR PALEOTOPOGRAPHY

Tertiary (?) sedimentary rocks (Tc)

A small exposure of sedimentary rocks (Tc, 4209.750N, 571.000 E) was considered by Ekren and others (1973) to be "Permian(?) or Pennsylvanian(?) in age, and to represent a structural window beneath a thrust(?)" that placed Silurian-Devonian carbonates

over these rocks. However, we found no evidence for a low-angle fault; these sedimentary rocks lie unconformably on Paleozoic carbonates. The nature of the northern contact with a small, east-striking, high-angle fault, which has little or no offset in the Paleozoic carbonates to the east or west, could not be determined due to poor exposure. The increase in angularity of lithic clasts in the conglomerate up section and toward this structure could suggest that this structure was active during deposition of parts or all of this sedimentary sequence, but any interpretation is equivocal without better exposure of the contact.

These Tertiary sedimentary rocks were most likely deposited in a paleo-valley. The sedimentary rocks are exposed at the bottom of a steep depression bounded to the north, south, and west by Paleozoic carbonates. Immediately to the south, tuffs of the Windous Butte Formation(?) rest depositionally on Paleozoic rocks (see discussion in following section). There is no evidence for a major fault in the Paleozoic section that would suggest that the present exposure is a function of faulting. Furthermore, the calcareous mudstones at the base of this section represent a quiet depositional environment, suggesting that sedimentation took place in a topographic low.

We suggest that this sequence of rocks was deposited on topography not unlike that observed today in the Reveille Range prior to the onset of significant Tertiary volcanic activity in the area. It is possible that the rocks were deposited in caverns such as those associated with karst environments today, but without more evidence for such an interpretation, a subaerial environment of deposition is preferred. These rocks are most likely Tertiary because they contain sparse volcanic rock fragments but Mesozoic or Paleozoic age cannot be precluded.

Windous Butte Formation(?)

Ekren and others (1973) considered their tuff of Williams Ridge and Morey Peak, which we call the Windous Butte Formation(?), to be the oldest volcanic unit in the northern Reveille Range (see unit descriptions on the map plate). They mapped most of the contacts between Windous Butte Formation(?) and other units in the quadrangle as faults, including the largest exposure (4208.500 N, 571.000 E) which is shown completely fault bounded. Jones and Bullock (1985) inferred that this exposure made up an east-trending graben bounded by Paleozoic sedimentary rocks. In contrast, we interpret the Windous Butte Formation(?) to have been deposited in a deep, east-trending paleo-valley in Paleozoic basement, an interpretation consistent with observations and conclusions presented in the previous section for unit Tc. Minor faulting has slightly modified the contacts.

Recent mining excavations provide excellent three-dimensional exposures along the southern contact with the Paleozoic carbonates. This contact is subvertical to moderately dipping and the compaction foliation in the Windous Butte Formation(?) fans from subvertical to moderately dipping at the contact to subhorizontal away from it. It is clear that this contact has been modified locally by subsequent minor faulting (brecciation and cataclasis are generally confined to the volcanic rocks), and by alteration of both volcanic and carbonate rocks by fluid migration along this contact. However, because of the lack of evidence for significant faulting and because the contact is highly irregular and sinuous in three dimensions, this contact is interpreted as a slightly disrupted depositional contact. The northern contact of Windous Butte Formation(?) against Paleozoic rocks is not well exposed and there is no clear evidence for a fault (brecciation or offset of lithologic markers) along this contact.

Tuff of Arrowhead

Ekren and others (1973) interpreted the tuff of Arrowhead to be almost completely fault-bounded by either strike-slip or thrust faults in both the southern Pancake Range and the northern Reveille Range; a single contact is shown as depositional on the tuff of Goblin Knobs in the Reveille Range. We suggest that most of these contacts are depositional.

Although the contact between the tuff of Arrowhead and the tuff of Goblin Knobs is in general poorly exposed, east of the Arrowhead district (4215.000N, 574.500 E), the tuff of Arrowhead lies depositionally on a thin lens (about 2-3 m thick) of well-rounded, volcanic-clast, cobble conglomerate that in turn lies depositionally on the tuff of Goblin Knobs. In addition, the tuff of Arrowhead everywhere rests on the lowest stratigraphic levels of the tuff of Goblin Knobs, and stratigraphically higher parts of the tuff of Goblin Knobs are topographically 50 to 100 m above the stratigraphically highest exposure of the tuff of Arrowhead. Together, these data indicate that the tuff of Goblin Knobs was deeply eroded prior to deposition of the tuff of Arrowhead.

FIELD EVIDENCE FOR CALDERAS IN THE REVEILLE QUADRANGLE

Since the study by Ekren and others (1973), a significant amount of Tertiary volcanological field data have been collected from the central Nevada region. Many studies indicate that numerous calderas formed during Oligocene and Miocene volcanism in central and south-central Nevada (Best and others, 1989, and references therein). The field relations described below indicate that the northern Reveille Range shared this protracted period of caldera formation.

Caldera of Goblin Knobs

As described by Ekren and others (1973) and here, there seems little doubt that the tuff of Goblin Knobs is an intracaldera deposit. Speculation as to the location of parts of the margins of this caldera of Goblin Knobs are presented here.

Evidence for the interpretation that the tuff of Goblin Knobs exposed in the eastern Reveille Range is intracaldera are: 1) it is more than 700 m thick and lacks internal cooling units; 2) it contains numerous large lithic fragments and pumice; 3) this thick sequence is juxtaposed against Paleozoic rocks to the west and outflow sheets to the north (Pancake Range); 4) the tuff of Goblin Knobs west of the Paleozoic rocks appears to be thin outflow; and 5) there is no evidence for strike-slip faulting across either boundary.

Geologic relations indicate the northern caldera wall must trend west-northwest through the pass separating the Reveille and Pancake Ranges (Ekren and others, 1973). The western wall is probably along the eastern side of the Paleozoic rocks in the Reveille Range. The most probable location for this contact is along the unexposed contact that juxtaposes the Windous Butte Formation(?) and the tuff of Goblin Knobs (formerly mapped as a strike-slip fault by Ekren and others, 1973, discussed above). In addition, locally, the Windous Butte Formation(?) is petrographically similar to the tuff of Goblin Knobs and these exposures may be outflow at the caldera margin. Clearly, subsequent volcanic activity, alteration, and range uplift have modified and obscured these relations and preclude more definitive placement of the western margin of the Goblin Knobs caldera.

Caldera of northern Reveille Range

Field relations described in the following section support the interpretation that part of the caldera from which the tuff of northern Reveille Range and probably the tuff of Streuben Knobs were erupted is in the northwestern part of the Reveille Quadrangle. However, until absolute age constraints are obtained for both these units, we hesitate applying the same name to them, and for this study retain the nomenclature set by Ekren and others (1973). This structure is hereafter referred to as caldera of northern Reveille Range.

Intracaldera facies

The tuff of northern Reveille Range is more than 300 m thick and contains numerous large lithic clasts and pumice. No internal cooling units could be defined. Along the southwesternmost contact of tuff of northern Reveille Range with Td (4716.500N, 568.000E) a 1- to 2-m thick, vertical to subvertical vitrophyre is exposed. This vitrophyre contains glassy pumice and clasts of Td and medium-grained granite, but no clasts of tuff of northern Reveille Range. The modal phenocryst percentages of the vitrophyre, and the granite and dacite clasts are similar to those found in tuff of northern Reveille Range (Tnr). There is at least 20 m of relief along strike of this vertical vitrophyre, which trends east-west along its eastern exposure and bends to a north-south strike to the west. In this locality, the adjacent welded tuff of northern Reveille Range contains a vertical flattening foliation that parallels the vitrophyre flattening foliation. Away from the vitrophyre, to the north, the vertical foliation in Tnr fans to subhorizontal over a distance of 25 to 50 m. To the south and topographically higher, limited exposures of the same vitrophyre resting on Td indicate that it is dipping shallowly to the south; Pliocene basalts rest unconformably on the vitrophyre.

Based on these observations, the vitrophyre is tentatively interpreted to have been plastered against and draped over part of the caldera wall of the caldera that erupted the tuff of northern Reveille Range. Immediately north and west of this structure, tuff of northern Reveille Range filled the topographic depression formed by collapse of the caldera. Fanning of the compaction foliation from subhorizontal to subvertical in this location represents cooling of the ponded tuff against the topographic wall bounding the caldera depression.

Ekren and others (1973) interpreted the north-striking contact between the tuff of Goblin Knobs and the tuff of northern Reveille Range in the north-central part of the quadrangle (4218.000N, 572.350E) as a set of left-lateral strike-slip faults and kinematically related thrust faults, but our close examination of exposures along this contact revealed no evidence for a strike-slip fault. This contact can be well located for 2 to 3 km along strike, and there is 50 to 100 m of vertical relief along this contact. Although the contact is nowhere directly exposed, rocks on either side and within 3 to 10 m of the contact are well exposed and show no evidence for the existence of a fault (brecciation, slickensides, or offset of geologic markers). Locally, silicified tuff of northern Reveille Range away from the contact contains numerous slickenlined fractures (neither slickenlines nor fractures have consistent orientations). However, markers such as lithic fragments and pumice indicate little or no displacement along these fractures. Because there is no evidence for brecciation or offset of geologic markers along the contact between the tuff of Goblin Knobs and the tuff of northern Reveille Range, either of which would support the existence of a fault, we interpret the contact as a buttress unconformity.

A silicified sequence of pyroclastic surge deposits, clastic sedimentary rocks, and megabreccia of the tuff of Goblin Knobs (Tsd) overlies the tuff of northern

Reveille Range along the north-striking contact with the tuff of Goblin Knobs (4218.650N, 472.300E). This sequence of rocks is interpreted to have formed by depositional ponding along the margin of a caldera that was still active (local vent eruptions producing small surge deposits). The megabreccia of tuff of Goblin Knobs may have broken loose from the unstable caldera wall and slid into the caldera of northern Reveille Range. The silicified, slickenlined fractures in the tuff of northern Reveille Range may be related to gravitational adjustments along this caldera wall. Furthermore, the tuff of northern Reveille Range and surge deposit (Tsd) are silicified along the north-striking contact with the tuff of Goblin Knobs. Caldera margins are known to localize hydrothermal fluids that lead to silicification of intracaldera fill (Burbank and Luedke, 1968; Lipman, 1984). This type of process may be responsible for the silicification observed.

The observations presented here, including the overall thickness and size of lithic fragments and pumice of the tuff of northern Reveille Range and the presence of tuff of Goblin Knobs lithic fragments within this tuff, demonstrate that the tuff of northern Reveille Range is younger than the tuff of Goblin Knobs. These observations suggest that part of the vent system and caldera margin of northern Reveille Range is exposed in the Reveille Quadrangle, probably nested within the caldera of Goblin Knobs. Based on these observations and those presented below for outflow facies of this caldera, the inferred position of a segment of the northern Reveille Range caldera margin is shown on the accompanying map and cross sections.

Outflow facies

The tuff of Streuben Knob of Ekren and others (1973) is interpreted here to be the outflow facies of the caldera of northern Reveille Range. This correlation is based on several field observations that include: 1) similar range in modal phenocryst percentages in tuffs of Streuben Knob and northern Reveille Range; 2) similar clast assemblages consisting dominantly of andesitic and dacitic lava and distinctive granitic clasts in tuffs of Streuben Knob and northern Reveille Range; 3) similar glassy pumice and lithic clasts in the basal vitrophyre of outflow facies and vertical to subhorizontal vitrophyre along the caldera wall of the tuff of northern Reveille Range; 4) spatial juxtaposition of both units; 5) relative thickness differences between the tuff of Streuben Knob and the tuff of northern Reveille Range; and 6) similar stratigraphic position of both the tuff of Streuben Knob and the tuff of northern Reveille Range. The following sections further outline the evidence for this correlation.

Rhyolite

Flow-banded rhyolite rests depositionally on the tuff of Streuben Knob. This rhyolite, named rhyolite of Streuben Knob by Ekren and others (1973), locally contains feldspar phenocrysts (0.5-2 cm) similar to those described for Trp intrusive bodies. Ekren and others (1973) considered the rhyolite and underlying tuff of Streuben Knob to be genetically related because both have similar modal phenocryst percentages and similar granitic clasts. Our study corroborates this interpretation. In the following section this genetic correlation is taken a step further by suggesting that the rhyolite of Streuben Knob is genetically related to the rhyolite-rhyodacitic porphyry plugs, dikes, and flow domes of unit Trp, and by association, to the tuffs of Streuben Knob and northern Reveille Range.

Northwest of Streuben Knob, on Hill 6956 (4214.750N, 567.500E), is an exposure of Trp that was previously mapped by Ekren and others (1973) as rhyolite of Streuben Knob. Flow banding in the rhyolite changes locally from subvertical to subhorizontal. At the top of Hill 6956, flow foliation in the rhyolite is subhorizontal but, down slope to the north, the flow texture disappears and the crystal-rich rhyolite is massive. Near the northern base of Hill 6956, the rhyolite has a medium-grained, (locally porphyritic) equant igneous texture (granite). Although the exposure is poor along the north face of Hill 6956, we suggest, based on this vertical textural variation, that Hill 6956 is composed of a rhyolitic flow-dome and that the deepest levels of exposure comprise the hypabyssal granitic portion of this body. This granite is texturally and petrographically similar to the granitic clasts found in units Tnr, Tst, and Tsr.

The contacts between this body and the tuff of Streuben Knob were mapped as two normal faults by Ekren and others (1973), but close scrutiny of these contacts revealed no evidence for faulting and we consider these contacts to be intrusive.

Rhyolite to Rhyodacitic Porphyry Plugs, Dikes, and Flow Domes

These bodies were mapped by Ekren and others (1973) as separate map units (see lithologic description). However, field observations made during this study suggest that these bodies may be genetically related. These observations include: 1) similar modal phenocryst percentages and bulk composition; 2) similar distinctive megacrysts of alkali feldspar; and 3) lack of intrusive relations with units younger than the tuffs of northern Reveille Range and Streuben Knobs. Furthermore, the field relations described above imply that the rhyolite of Streuben Knobs is also genetically related to this group of intrusions.

By association, then, the rhyolite tuffs of northern Reveille Range and Streuben Knobs (Tnr and Tst), rhyolite flow (Tsr), surge and sedimentary deposits (Tsd), and rhyolitic to rhyodacitic intrusive bodies (Trp) are, based on these field observations, tentatively considered genetically related. Most bodies of Trp appear to be spatially associated with the inferred caldera margin of the tuff of northern Reveille Range. These units are considered genetically related and associated with the eruption and subsequent volcanic/intrusive development of the caldera of northern Reveille Range. Without further geochronologic or geochemical studies to confirm or refute the interpretations presented here, a minimum age of formation of the caldera of northern Reveille Range is considered 19.3 Ma, the age of dikes and plugs in the unit Trp (K-Ar, sanidine, Ekren and others, 1973).

Miocene Breccias

Volcanic-debris-bearing breccia sheets exposed locally in the Reveille Quadrangle and in the vicinity of the pass separating the southern Pancake Range from the northern Reveille Range were interpreted by Ekren and others (1973) to have formed during a period of intense strike-slip faulting between 18.5 and 26.0 Ma. In the absence of field evidence supporting the existence of these faults and the inferred presence of two calderas in the northern Reveille Range, we interpret these deposits to be associated with these calderas. Debris avalanches are abundant on steep caldera margins (Lipman, 1984), which may have been common in the northern Reveille Range at the time of development of the calderas of Goblin Knobs and northern Reveille Range. Because of their stratigraphic position, the breccias (Tbr) exposed in the Reveille Quadrangle are most likely to be related to the caldera of Goblin Knobs.

PLIOCENE BASALT

Pliocene basaltic volcanism represents the last period of volcanic activity in the Reveille Quadrangle (Ekren and others, 1973; Naumann and others, 1991). Two episodes of isotopically distinct basalts have been recognized. Basalts of Episode 1 are 5.0 to 5.9 Ma and have $^{87}Sr/^{86}Sr$ values that range from 0.70423 to 0.70611 and eNd values that range from +0.82 to +4.45. Basalts of Episode 2 are 3.0 to 4.6 Ma and have $^{87}Sr/^{86}Sr$ values that range from 0.70337 to 0.70359 and eNd values that range from +3.49 to +5.33 (Naumann and others, 1990, 1991; Yogodzinski and others, 1994). Two evolved, explosive trachytic to tristanite domes were emplaced during and between basaltic episodes (Naumann and others, 1990). The larger of these domes is immediately northeast of the quadrangle and has a K-Ar age (plagioclase) of 4.24 ± 0.06 Ma (Naumann and others, 1991). The smaller dome is located along the east-central edge of the Reveille Quadrangle and has a K-Ar age (plagioclase) of 4.39 ± 0.18 Ma (Naumann and others, 1991; Tbt, see map and unit descriptions). Initial explosive eruption at both domes produced a pyroclastic apron between 2 and 10 m thick (Naumann and others, 1991; Tca, see map and unit descriptions).

Basaltic vents are located in the central part of the range as well as on the range flanks. All Episode 1 basaltic vents and their associated flows within the range rest directly on Tertiary rocks without intervening alluvial sedimentary rocks or detritus. In addition, Episode 1 basalt flows along the east flank of the Reveille Range (for example, 4212.500N, 576.500E) originated from vents at high topographic levels and flowed down steep gradients (>30°) into the flanking alluvial basin. These field relations support the conclusion that the basaltic vents that are presently within the range erupted during or after uplift of the range.

On the west flank of the Reveille Range, Ekren and others (1973) mapped several north-striking normal faults cutting Pliocene basalt flows. The existence of these faults is ambiguous. A zone of north-trending brecciation occurs in pre-Pliocene Tertiary tuffs at the present level of exposure, presumably the result of a fault. However, we could not determine if the overlying basalts are also faulted. These field relations permit the following interpretations: 1) the basalts are not faulted, but flowed over a preexisting fault scarp; 2) the oldest basalt flows have been faulted and subsequent flows have flowed over this fault scarp; or 3) the entire sequence of basalt flows is faulted as indicated by Ekren and others (1973). The present exposure in this area does not allow a definitive interpretation. The field relations discussed above from the eastern side of the range, however, support the interpretation that these basalts erupted synchronously with, or after development of, range-bounding normal faults.

CONCLUSIONS

The Reveille Range records a protracted history of Tertiary volcanism but provides little evidence for the intense strike-slip faulting inferred by Ekren and others (1973). The oldest Tertiary volcanic unit, Windous Butte Formation(?), and Tertiary(?) sedimentary rocks (Tc) in the Reveille Quadrangle are inferred to have been deposited on an irregular topographic surface cut into Paleozoic marine sedimentary rocks. In addition, subsequent volcanic units were deposited on steep topography associated with two inferred Miocene calderas. Previous workers (for example, Ekren and others, 1973; Jones and Bullock, 1985) interpreted these irregular depositional contacts as faults. The tuff of Goblin Knobs (24.5 Ma) erupted from a caldera, a part of

which is located in the northern Reveille Range; a segment of the northern margin of this caldera lies between the southern Pancake Range and the northern Reveille Range. Older volcanic and Paleozoic units in the range probably formed the western margin of the caldera of Goblin Knobs.

The tuff of northern Reveille Range erupted from a younger caldera, a part of which is also in the northern Reveille Range and possibly nested within the caldera of Goblin Knobs. The tuff of Streuben Knob is inferred to be an outflow sheet correlative to the intracaldera tuff of northern Reveille Range. The rhyolite of Streuben Knob and rhyolite porphyry plugs and dikes are also inferred to be genetically related to the caldera of northern Reveille Range. An unpublished K-Ar age of 19.3 Ma from these porphyry dikes places a minimum age on this caldera of 19.3 Ma.

Between 6 and 3 Ma, two isotopically distinct basalts were erupted in the Reveille Quadrangle. Intermediate volcanism consisting of two evolved, explosive trachytic to tristanite domes occurred during and between basaltic volcanism. The lack of intervening sedimentary rocks between Pliocene basalts and older Tertiary volcanic rocks in the study area, steep primary flow fabrics along the flanks of the range, and the lack of conclusive field evidence that basalts are cut by normal faults suggest that Pliocene basaltic volcanism occurred during or after movement on range-bounding normal faults responsible for uplift of the range.

ACKNOWLEDGMENTS

Funds for this work came from the Center for Volcanic and Tectonic Studies (CVTS) under the direction of E.I. Smith at the University of Nevada, Las Vegas. This work was completed during post-graduate (MWM) and graduate (TRN) studies at CVTS. Drew and Sharla Coleman are thanked for their brief but able field assistance. The authors appreciate helpful and critical reviews from J.M. Bartley, M.G. Best, R.E. Hardyman, C.D. Henry, and E.I. Smith. Editorial comments from M.L. Enos are also greatly appreciated.

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