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NORTHUMBERLAND CALDERA AND NORTHUMBERLAND TUFF

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INTRODUCTION

Eruptive rocks from a volcanic center and tectonic features resulting from its collapse define a caldera in the vicinity of Northumberland Canyon on the west edge of the Toquima Range (see fig. 1 of *Road Log*). The northeastern edge of the caldera is especially well exposed in Northumberland Canyon, where ash flows, lava flows, enormous landslide blocks, and chaotic rubble of Paleozoic rock and water-laid sedimentary strata indicate collapse and rapid filling of the caldera after eruption of a thick composite ash-flow sheet herein named the Northumberland Tuff. The entire caldera occupies an area about 20 miles in diameter, and the collapsed rim can be traced, with only slight modification by later faulting, around the eastern half of the feature. The western half is buried beneath the alluviated Big Smoky Valley. South of the caldera the Northumberland Tuff extends over the Paleozoic basement for perhaps 10 miles as a thin veneer of ash flows that probably erupted prior to collapse of the caldera.

NORTHUMBERLAND TUFF

The name Northumberland Tuff is here adopted for exposures of tuff in the area of Northumberland Canyon on the west side of the Toquima Range, central Nevada. The type section is located in the north-central part of sec. 8 (unsurveyed), T. 13 N., R. 45 E., about 1 mile south of Northumberland Canyon, Wildcat Peak quadrangle. An alternate section, the reference section, contains many good exposures in the continuous outcrops that extend southeast from the type section for about 3 to 5 miles. At the type and reference sections, the lower contact is not exposed, and the upper contact is an erosion surface. The formation is generally at least 1,000 feet thick, and probably at least twice as thick in the type section.

Characteristics of the Ash-flow Sheet

The Northumberland Tuff is a composite ash-flow sheet consisting of numerous individual ash flows in a sequence separated by partial cooling breaks, and locally at least two complete cooling breaks marked by lenses of sedimentary strata and zones of black vitrophyre. The partial breaks give the body of tuff a subtle but distinct stratified look (fig. 1), and appear in the outcrop as discontinuous subhorizontal planes traceable for distances of as much as a mile. The zones representing complete cooling breaks pinch out along strike into the main pile of tuff. The welded tuff throughout the ash

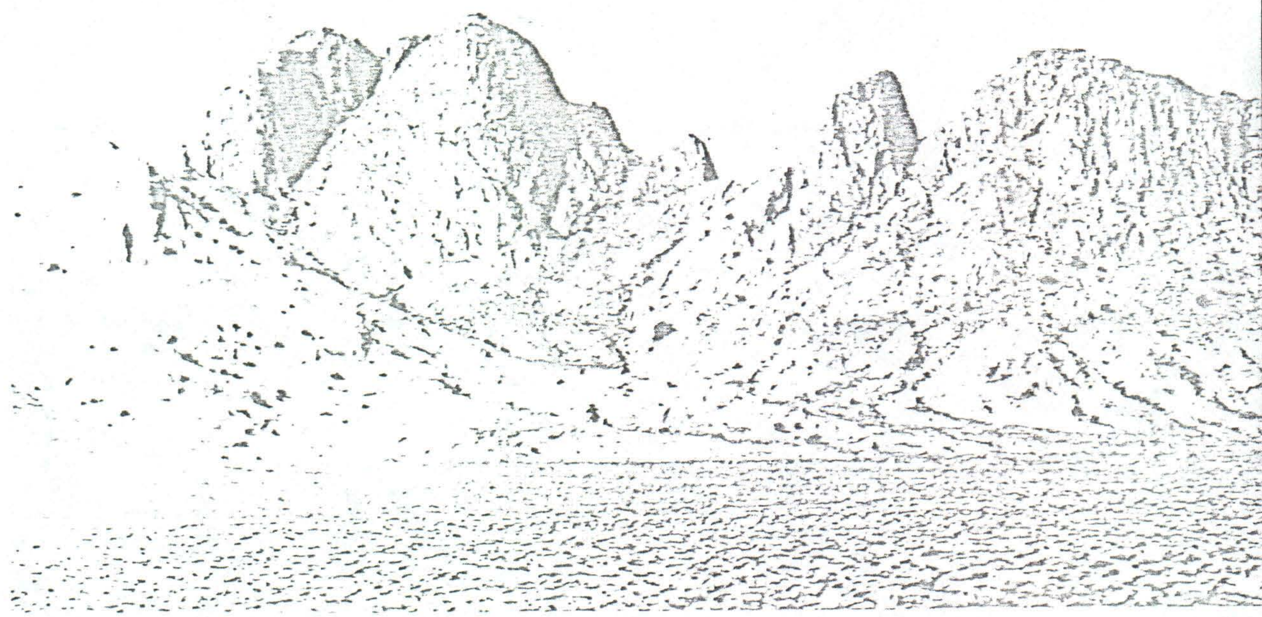
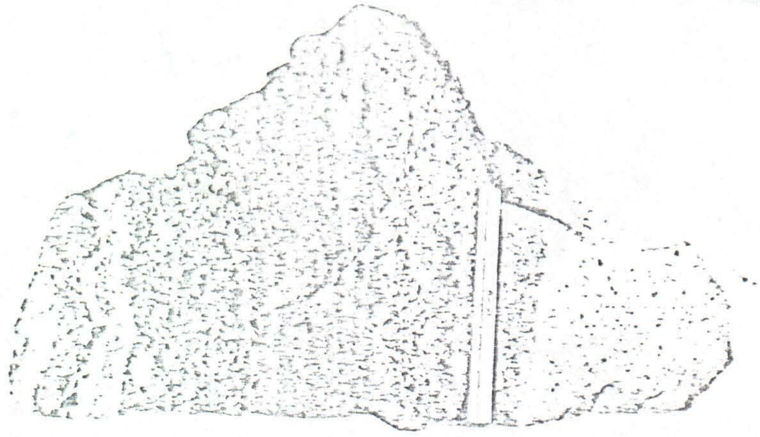


FIGURE 1. Northumberland Tuff, a thick composite ash-flow sheet. Note columnar jointing and planar subhorizontal partial cooling breaks. View south from the mouth of Northumberland Canyon.

FIGURE 2. Silicified chert conglomerate, sandstone, and grits on top of a thin rhyolite flow (only top 10 cm shown here at bottom of photograph). These rocks accumulated after the collapse of the caldera.



flow is similar except for slight and nonpersistent differences in compaction and welding. Locally, columnar joints cut across the horizontal partings, indicating that although individual ash flows cooled partially before they were covered by succeeding flows, the entire pile completed cooling as a whole.

Within and outside the southern part of the caldera the Northumberland Tuff is thinner than elsewhere, and exhibits characteristics more typical of far-traveled ash flows. Eutaxitic fabric is more definite, and the unit, which has a visible bottom, shows subhorizontal compaction features and welded zones. Included in the Northumberland Tuff are some thin lava flows (fig. 2) and compacted silicified ash beds that are the final eruptive products of the volcano. These rocks are interbedded with sedimentary strata (fig. 3), including large landslide blocks, that form a lenticular wedge of material distributed circumferentially within the caldera.

Dimensions of the Ash-flow Sheet

The ash-flow sheet covers an area of about 80 square miles (fig. 4) of which about half is within the area of the collapse caldera. Within the caldera (fig. 5) and near the eruptive vents, the tuff is at least 1,000 feet thick and was probably more than twice this thick before erosion removed the upper parts of it. Outside the caldera the ash flow is 100 feet thick or less. An estimate of the volume of tuff erupted is on the order of 15 cubic miles. By comparison, about a fifth as much material was erupted here as from the similar Fish Creek Mountains volcanic center some 75 miles to the northwest, where an estimated 75 cubic miles of welded tuff, the Fish Creek Mountains Tuff (McKee, 1970), was ejected. The Northumberland Tuff sheet is considerably smaller than many of the better known and more widespread ash-flow sheets of central Nevada (Bates Mountain Tuff, cooling unit

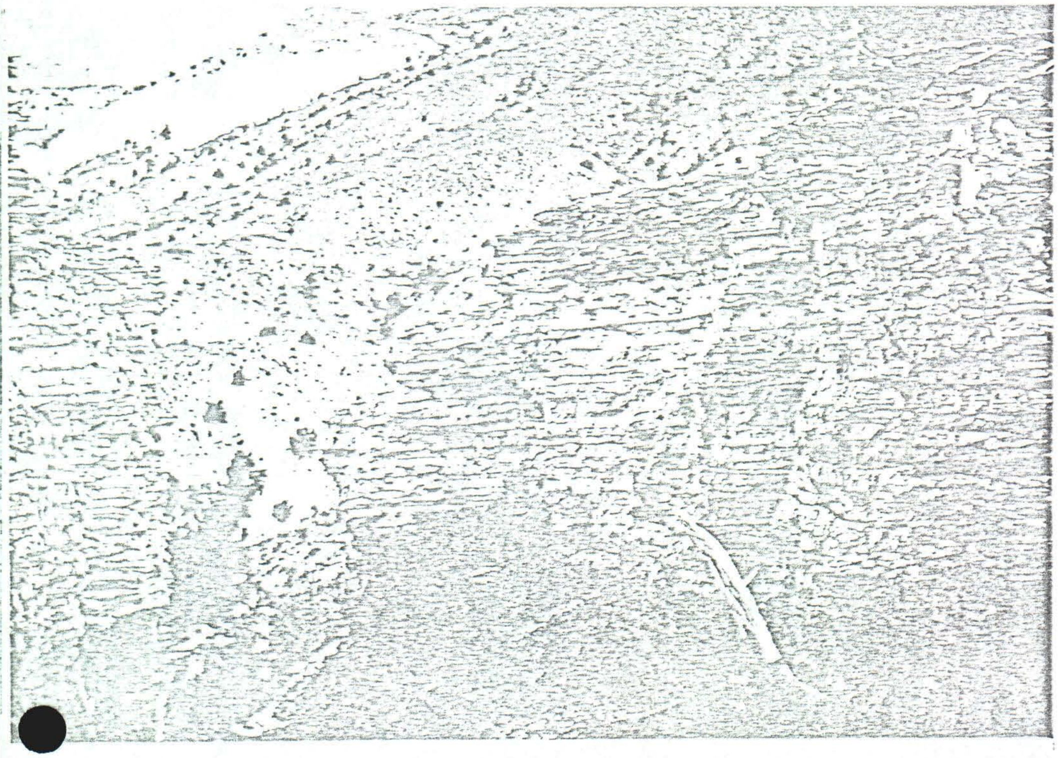


FIGURE 3. Well-stratified water-laid tuffaceous sedimentary rocks north of Northumberland Canyon. These strata accumulated in the peripheral area within the collapsed caldera.

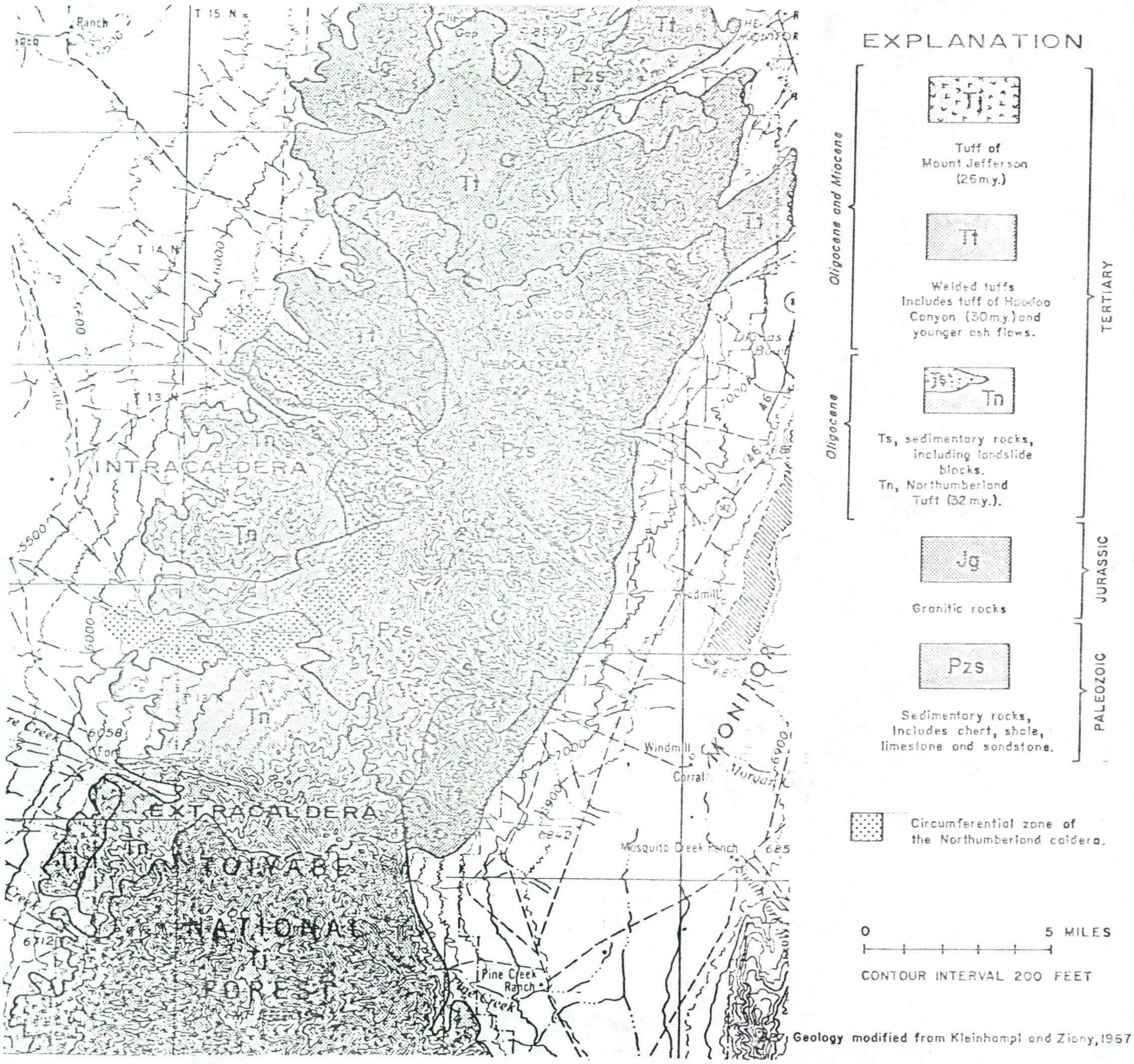
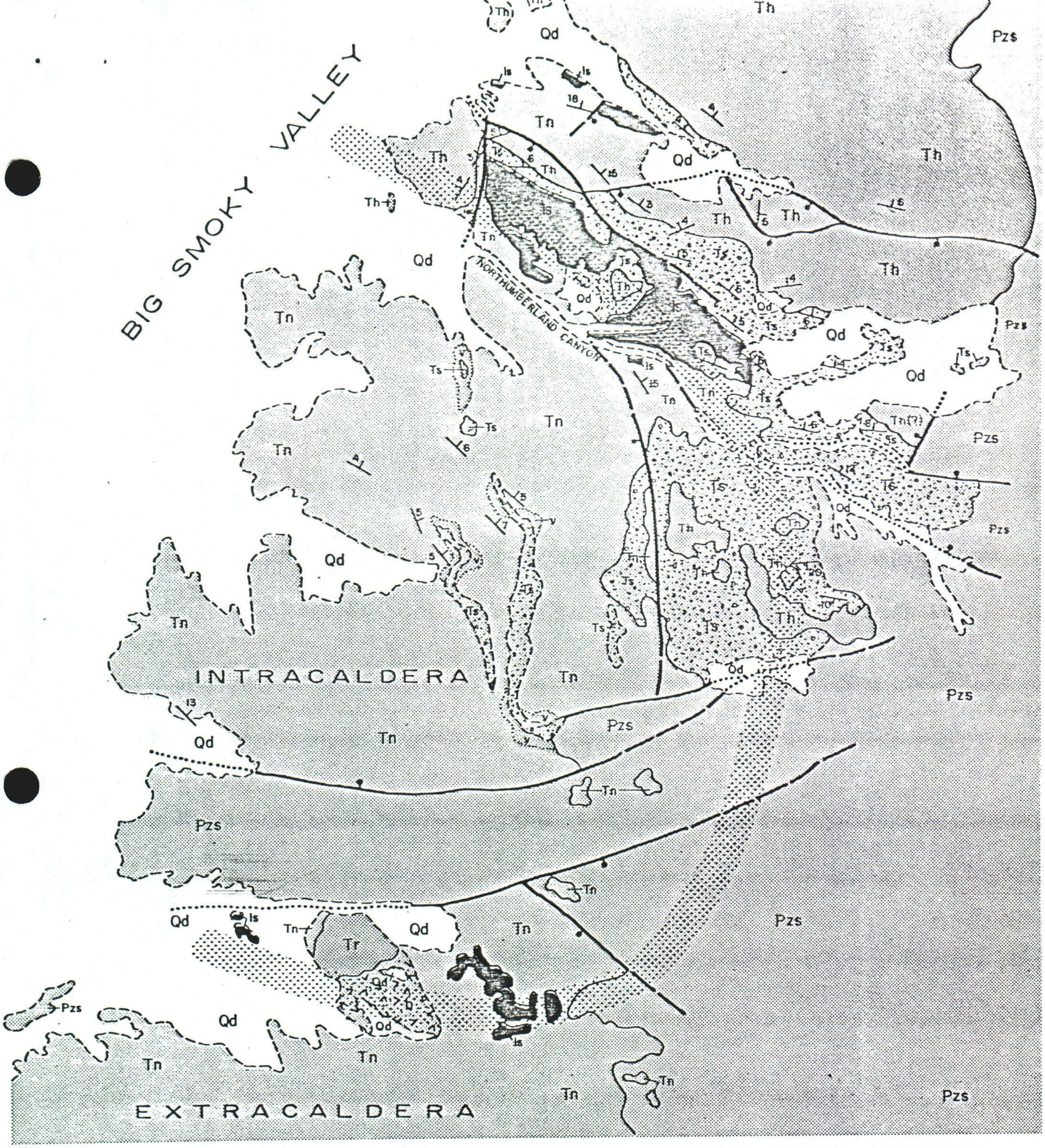


FIGURE 4. Geologic map of the central part of the Toquima Range (modified from Kleinhampl and Ziony, 1967), illustrating the regional setting of the Northumberland caldera.

D, 300 cubic miles; Windous Butte Formation, 780 cubic miles; Pancake Summit Tuff, 450 cubic miles; and the upper member of Cook's (1960) Stone Cabin Tuff, 210 cubic miles; Gromme and others, 1972, table 1).

Lithology

The Northumberland Tuff is gray to white, rich in crystals, and of rhyolitic composition. Most of it is welded tuff of ash-flow origin, and less voluminous tuff breccia and flow-laminated lavas are mapped with the unit. Thin sections (fig. 6) of the welded tuff show between 20 and 35 percent crystals in a matrix of devitrified glass shards. Quartz and sanidine in about equal amounts are the principle minerals present; biotite and plagioclase are rare but ubiquitous. In places biotite is concentrated and comprises as much as 5 percent of the phenocrysts. Lithic fragments, almost exclusively Paleozoic chert, are scattered throughout the tuff but are larger and more abundant in the upper parts of the ash-flow sheet.



EXPLANATION

QUATERNARY — Qd — Quaternary deposits

TERTIARY, Oligocene or Miocene — Tr — Rhyolite dome (26 m.y.)

TERTIARY, Oligocene — Th — Tuff of Hoodoo Canyon. Biotite-rich welded tuff. (30.4 m.y.)

TERTIARY, Oligocene — Northumberland caldera fill; Pre-Northumberland caldera — Ts, Is, Tn — Northumberland Tuff and associated rocks:
Ts, sedimentary rocks: conglomerate, sandstone, and siltstone; waterworked.
Is, landslide blocks and chaotic breccia of Paleozoic rocks.
Tn, Northumberland Tuff; crystal-rich rhyolite welded tuff and some lava flows. (32.3 m.y.) v - vitrophyre zones, b - breccia zones.

PALEOZOIC — Pzs — Sedimentary rocks

Circumferential zone of the Northumberland caldera.

ONE MILE

FIGURE 5. Geologic map of the Northumberland Canyon area.

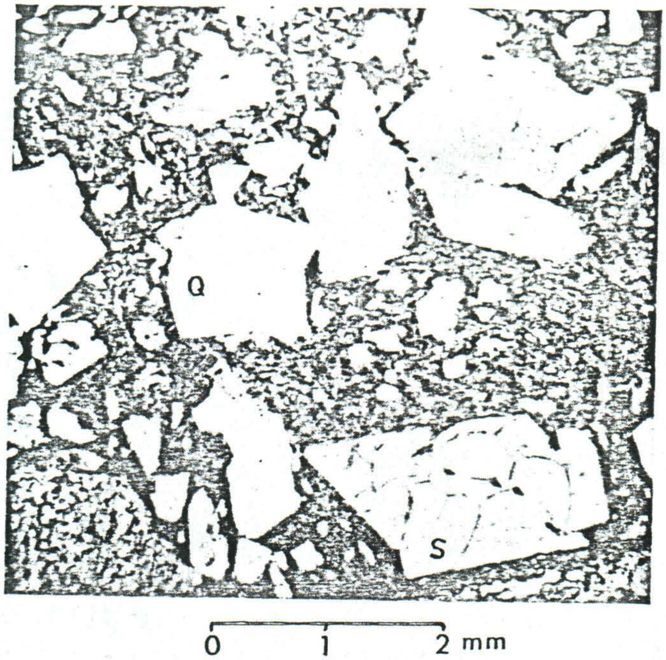


FIGURE 6. Photomicrograph in plain light of a sample of the Northumberland Tuff collected south of the mouth of Northumberland Canyon. Note cracked crystals of quartz (Q) and sanidine (S), and one fragment of chert (C) surrounded by oriented and flattened shards.

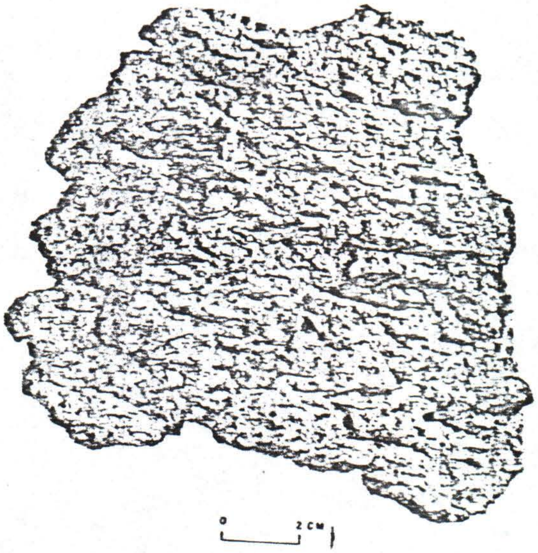


FIGURE 7. Northumberland Tuff from south of the caldera. Here the ash flow is thin, and displays subhorizontal compaction features and welded zones characteristic of far-traveled ash-flow sheets. Note weathered-out flattened pumice.

Hand specimens collected from the thickest, central part of the sheet do not exhibit obvious welded tuff structures such as eutaxitic texture, elongate gas cavities, or flattened pumice fragments, but oriented and flattened shards bent around cracked crystal phenocrysts are seen in thin section. Parts of the sheet in the area south of the caldera are more obviously a welded tuff, and contain megascopically discernible flattened pumice, elongate gas cavities, and eutaxitic fabric (fig. 7).

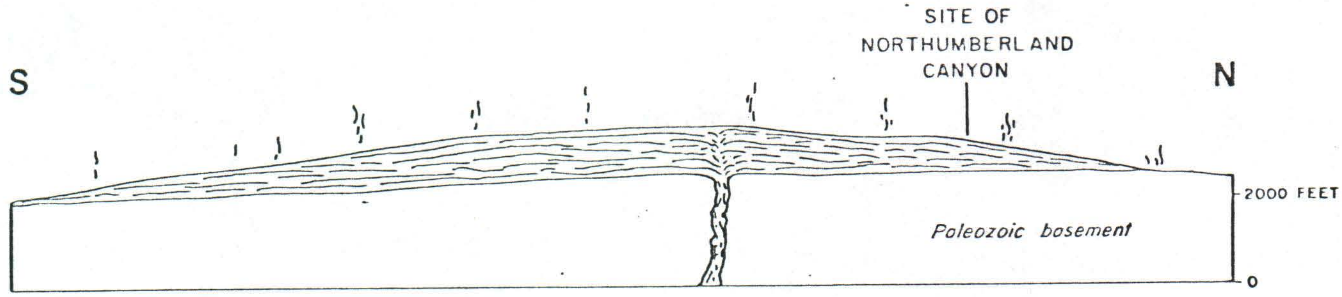
Chemistry

Chemical analyses indicate that the rock is rhyolite (table 1). These analyses compare closely with the 'average calc-alkali rhyolite and rhyolite obsidian' of Nockolds (1954) although they are poorer in total Fe and Mg. Nontypical softness and abundant limonite-stained fractures and liesegang banding characterize the tuff below the large landslide blocks of Paleozoic rocks. A sample of tuff from about 30 feet down into this zone yielded chemical data (table 1, no. 3) indicating considerable enrichment and oxidation of Fe, an increase in H_2O^+ and CO_2, and a loss of SiO_2, Al_2O_3, and alkalies. It seems most likely that the alteration beneath the landslide blocks was the result of relatively prolonged and concentrated action of vapors trapped beneath the landslide barriers during migration upward from the hot pile of ash-flow tuffs. The bottom of the large blocks, as well as smaller xenoliths of Paleozoic rock at greater depth in the tuff, are strongly discolored and bleached, suggesting an episode of intense heating and reaction with the once-hot tuff. An alternate hypothesis is that the zone of iron-stained and altered tuff may represent supergene leaching and downward transport of iron from the dark chert and siltstone of the landslide blocks. In any case, the position of the landslide blocks on and partly incorporated in the tuff suggests that they were emplaced or slid into the tuff while it was still partly hot.

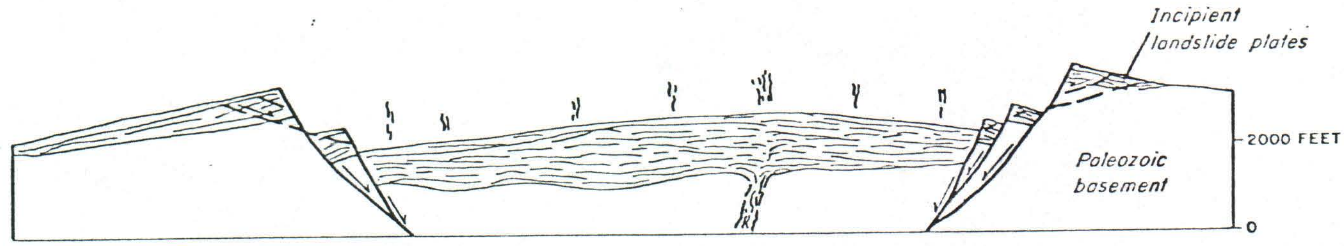
TABLE 1

Chemical analyses of two samples of unaltered Northumberland Tuf and one sample of altered tuff from same formation from beneath a large landslide block of the Ordovician Vinini Formation

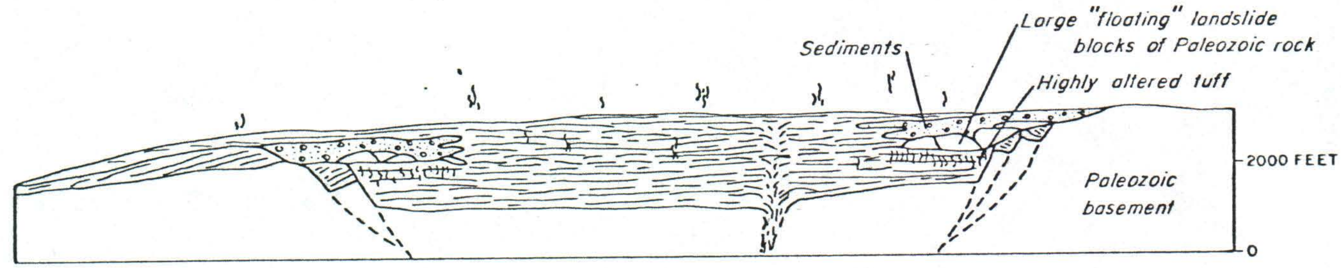
	Unaltered samples no. 1	Unaltered samples no. 2	Altered samples	Change betwee unaltered and altered samples
SiO_2	73.2	75.6	65.5	Probable los
Al_2O_3	14.3	12.9	10.1	Probable los
Fe_2O_3	.27	.29	11.8	Gain
FeO	.40	.26	.28	
MgO	.14	.19	.18	
CaO	1.1	.94	1.2	
Na_2O	3.4	3.0	1.0	Loss
K_2O	5.4	4.9	4.2	
H_2O^+	.69	.49	3.4	Gain
H_2O^-	.51	.71	.57	
TiO_2	.22	.25	.25	
CO_2	.05	.05	.58	Gain
P_2O_5	.03	.00	.10	
MnO	.02	.00	.00	



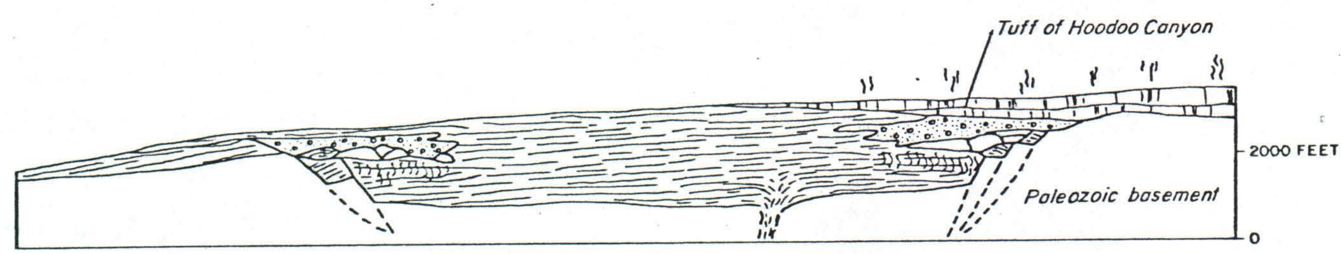
A. Initial eruptive stage about 33 m.y. ago. Emplacement of a thick composite ash-flow sheet.



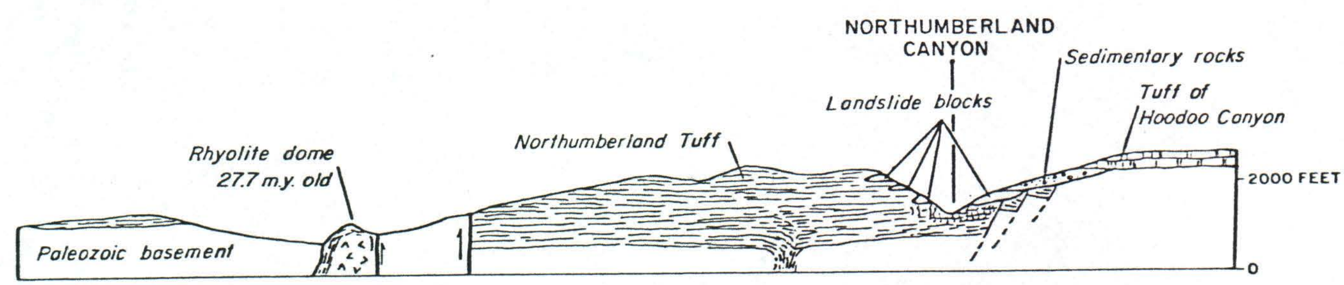
B. Collapse of ash-flow sheet to form caldera. The thick ash-flow sheet still hot and emitting vapor.



C. Caldera fill, mostly sedimentary rocks peripherally located and ash flows in central area. About 32-31 m.y. ago.



D. Volcano-tectonic cycle complete. Tuff of Hoodoo Canyon overlaps northern part (and possibly all) of filled caldera.



E. Present level of erosion, caldron structure modified by basin-and-range faulting.

14 MILES

FIGURE 8. Schematic inferred history of the Northumberland Canyon volcanic center and caldera. Horizontal scale approximate, vertical scale exaggerated about 2X.

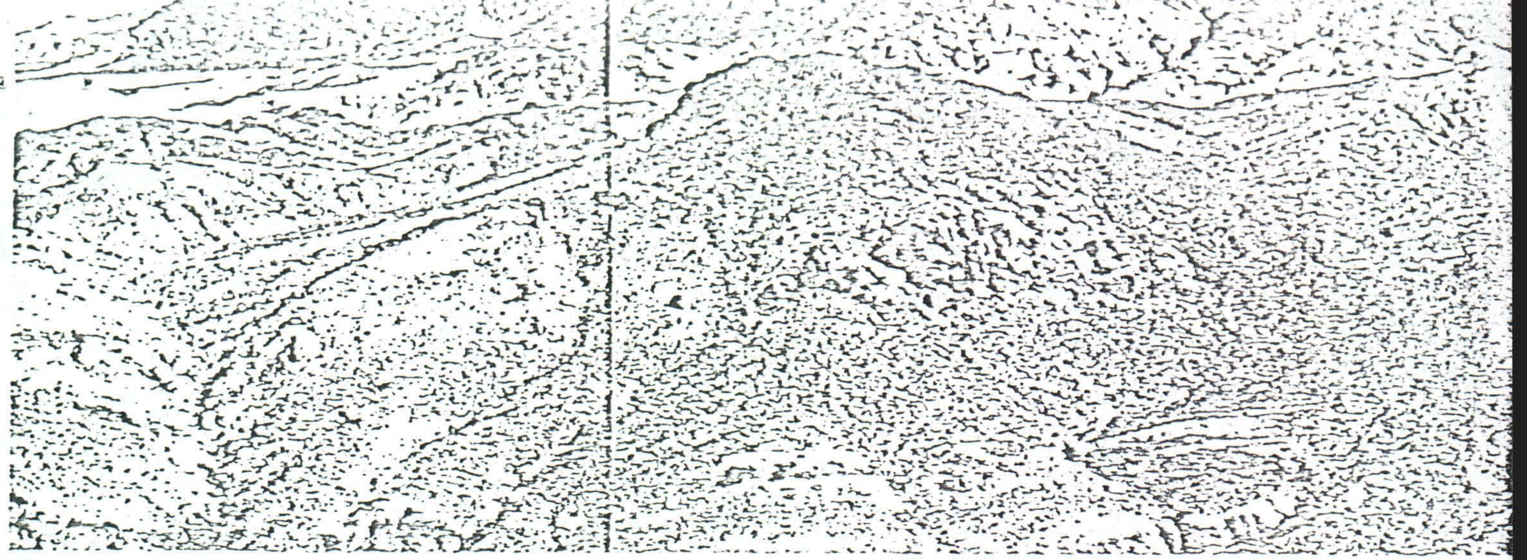


FIGURE 9. Large landslide block of Ordovician Vinini Formation (block) "floating" on Northumberland Tuff. Note irregularly resistant welded tuff directly beneath the block. The block is significantly more altered than at other places in the ash-flow sheet. It is a landslide mass that has slid inward from the rim that formed by collapse of the caldera. Rocks in background are the tuff of Hoodoo Canyon, a younger and unrelated ash-flow sheet.

Age

The Northumberland Tuff is considered to be Oligocene on the basis of a K-Ar determination of 32.3 ±1 m.y. on sanidine from rock collected on the south side of the Northumberland Canyon road, north of the center of sec. 9 (unsurveyed), T. 13 N., R. 45 E. (the photomicrograph, fig. 6 is from this specimen). The ash flow is very thick here, and the sample is judged to be from fairly deep within the ash-flow pile, and therefore probably represents tuff erupted prior to collapse of the caldera but certainly neither the oldest nor youngest material. The duration of volcanic activity at the Northumberland Canyon center is not known, but an upper limit of 30.4 m.y. is fixed by the age of the overlying tuff of Hoodoo Canyon. A reasonable estimate of the period of eruption is about 1 m.y. on the basis of the dates recorded here, and from what is known about eruptive histories of some other centers that formed collapse calderas—the Silent Canyon volcanic center in Nye County, Nevada (Noble and others, 1968), and the first, second, and third volcanic cycles of the rhyolite plateau in Yellowstone National Park (Christiansen and Blank, 1972).

ERUPTIVE AND TECTONIC HISTORY

Eruption about 33 m.y. ago of low-energy ash flows from vents in a shallow magma chamber located immediately south of Northumberland Canyon, formed a volcanic pile at the site of eruption, and a thin veneer that spread for about 15 miles in a predominately southerly direction, marked the start of volcanism at this center (fig. 8a). After a considerable volume of tuff had erupted, collapse of the volcanic center resulted in formation of a caldera (fig. 8b). Blocks of Paleozoic basement strata as much as a mile across broke from the caldera rim and slid onto the hot ash-flow sheet inside the caldera, some partly sinking into the tuff (fig. 9). Beneath these barriers of relatively impermeable rock, hot vapor migrating upward caused alteration of the tuff, and leaching, discoloration, and silicification of the bottom part of the blocks. Continued volcanic activity filled the central part of the caldera and added to the wedge of clastic detritus, including the landslide blocks, that filled the peripheral part of the caldera (fig. 8c). Postcollapse ash flows accumulated to a thickness of about 1,000 feet in the center of the structural basin, and sedimentary rocks to a thickness of several hundred feet around the margin.

Evidence of resurgence of the central part of the collapse structure, typical of many calderas, is unclear. The central part of the Northumberland caldera is a deeply dissected body of tuff, the basal contact of which is not exposed at the present level of erosion. It is possible that the thick pile has been domed upward and that some of the more deeply exposed rocks are intrusive types with the same composition as the ash flow. The fact that the sedimentary rocks are distributed circumferentially within the caldera and are not present in the center may be explained in several ways and bears partly on the subject of resurgence: (1) the central area quickly filled with volcanic rocks after collapse, possibly but not necessarily with accompanying resurgence, (2) the central area resurged before or immediately after the ash flow eruptions ceased, or (3) the central area was uplifted at some later time, and possible accumulated sedimentary rocks were completely removed by erosion.

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