EARL M. P. LOVEJOY *Department of Geological Sciences, The University of Texas at El Paso, El Paso, Texas 79968*

Nonantecedent Development of Truckee River Canyon, Northern Carson Range, Nevada and California

ABSTRACT

Truckee River crosses northern Carson Range in a gorge 3000 ft deep, passing east from Truckee Valley, elevation 6400 ft, to Truckee Meadows, elevation 4400 ft. A suggested nonantecedent origin for this gorge is based on headward erosion in the easily eroded pyroclastic rocks which lie on the resistant Sierran basement intrusive rocks. Headward erosion, associated with stream capture of northward- and northwestward-trending drainage from a high volcano enabled Truckee River to extend west of the original range divide, where it incorporated drainage of the western flank and continued by headward erosion into Truckee Valley, thus crossing the Carson Range nonantecedently. Therefore, Truckee River Canyon may not be evidence of postandesite uplift, either by warping or faulting, of the Carson Range.

INTRODUCTION

The close relationship between geomorphology and structure in the northern Sierra Nevada and its easternmost spur, the Carson Range has been accepted for many years (Lindgren, 1897; Louderback, 1904, 1907; Lawson, 1912). Tectonic interpretations have been based on structural interpretations which, in turn, have depended on geomorphic analysis. The geomorphic youthfulness of the scarp along the eastern front of the range south of Mount Rose has impressed geologists, and many of them unfamiliar with the desert conclude that geomorphic youthfulness indicates geochronologic youthfulness. The two are not equal.

The Truckee River course through northern Carson Range (Fig. 1) was explained by Lindgren (1897): "Truckee Valley, first a lake,

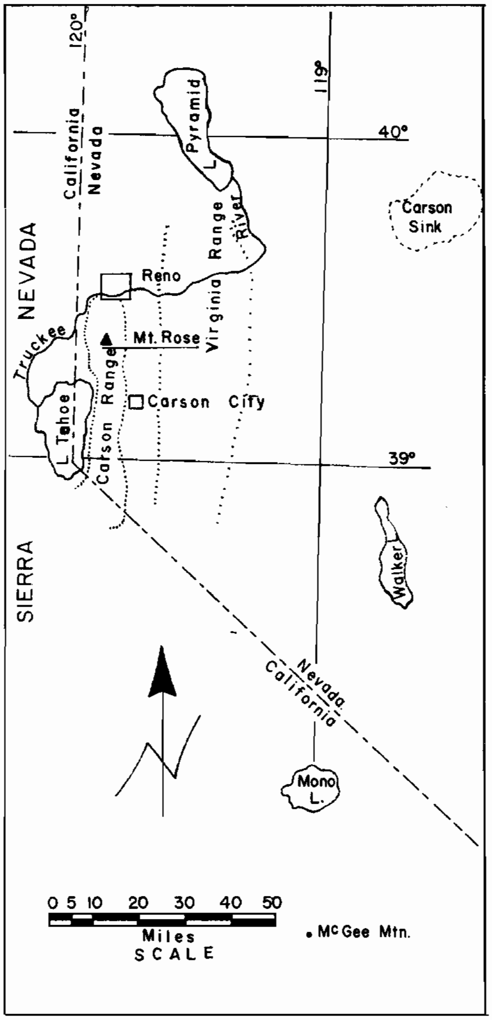

Figure 1. Regional index map of north-central Sierra Nevada and northwestern Nevada (Lovejoy, 1969, Fig. 1, p. 1834).

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found soon after the close of the volcanic period an outlet along the present Truckee River across the eastern or Carson Range, the outlet probably following an original depression in the surface of the andesites."

Lindgren thought that the volcanic rocks (Mehrten or Kate Peak Formations, or both, late Miocene to early Pliocene andesite flows and pyroclastic rocks) had been deposited on an already uplifted Carson Range fault block to form a surface on which a drainage pattern developed. However, Louderback (1904, 1907) using geomorphic evidence convinced Lindgren (1911) of postvolcanic fault displacement of 5000 ft along the eastern front of the Carson Range at Mount Rose.

Sales (1962), and Birkeland (1968, p. 472) accepted an antecedent origin for the Truckee River Canyon by assuming postvolcanic uplift of the range by faulting (Louderback, 1904, 1907, 1923, 1924, 1926) or warping (Thompson and White, 1964; Birkeland, 1968, p. 472).

Thus, a nonantecedent origin of the Truckee River Canyon would bear on the problem of tectonic development of the Sierra Nevada.

There is doubt about the interpretation of late Pliocene and Pleistocene relative uplift of the Sierra Nevada with respect to the Basin and Range province along the eastern frontal fault zone (Lovejoy, 1960, 1964, 1966, 1968a, 1968b, 1969). The evidence at Mount Rose may also be due to erosion of a large volcano formed on rugged terrain (Lovejoy, 1968, Fig. 9). Thus, Lindgren's original idea (1911, p. 39–45) must be reviewed.

Flows and pyroclastic rocks cover the granite in the Carson Range. According to the view presented here pyroclastic material and lava flows emanated from several vent areas, principal among which was the Hill 9400 volcano (Thompson, 1952; Lovejoy, 1969). These locally interfingering materials were deposited on a pre-existing Carson Range and adjacent basins. The tuffs were deposited originally on the steep slopes of the range, both above and below the lake water level. Sublacustrine slumping (similar to that in Chalk Hills of the Virginia Range where intense folding and vertical dips in lacustrine tuff and diatomite occur; *see* Thompson, 1956) produced faulting and folding of the tuff on the east flank of the Carson Range in Truckee Meadows. Compaction faulting and minor tectonic faulting dislocated all of the deposits.

The subvolcanic granite ridge of the prevolcanic Carson Range slopes northward from beneath Mount Rose at an elevation of about 5800 ft. Thus in the Carson Range the volcanic deposit is much thicker north of Mount Rose than south of it.

GEOGRAPHY AND GEOLOGY OF THE NORTHERN CARSON RANGE REGION

The eastern side of the northern Carson Range (Fig. 2) is parallel to the trends of Carson Valley, Eagle Valley, Washoe Valley, and Truckee Meadows (elevation 4400 ft). The western side of the range is bounded by the Lake Tahoe depression, the Martis Peak–Mt. Pluto volcanic pile, and Truckee Valley depression. North of Truckee River Canyon is Peavine Mountain, the northward continuation of the Carson Range.

The Truckee River heads at Lake Tahoe, flows northward through a canyon cut in the Mt. Pluto–Martis Peak volcanic pile (Fig. 2), emerges into Truckee Valley where it cuts through a succession of Neogene strata, and plunges into Truckee River Canyon on the west flank of the Carson Range. It then turns northward about 10 mi, then east to flow into Truckee Meadows at Reno. The north-trending reach along the Carson Range is an important feature. Truckee Canyon has steep walls 3600 ft high, but the river has cut 5000 ft below the Carson Range summit. The genesis of this canyon is the subject of this paper. (See Birkeland, 1963, and 1968 for a complete description of the pertinent geology.)

GENESIS OF DRAINAGE IN THE NORTHERN CARSON RANGE

The course of the Truckee River from Lake Tahoe to Truckee Valley was explained by Lindgren (1897). His interpretation for the course through Truckee Canyon requires a lake elevation equal to that of the lowest pass through the range.

Birkeland (1962, 1963) showed that Truckee River Canyon is younger than Plio-Pleistocene Lousetown flows which extend over the Truckee River Canyon near Bronco Creek at 7000 ft (*see* Thompson and White, 1964, Pl. I, and Burnett and Jennings, 1962). No post-Lousetown lake deposits have been found at such high elevations in the range.

Thompson and White (1964) show that

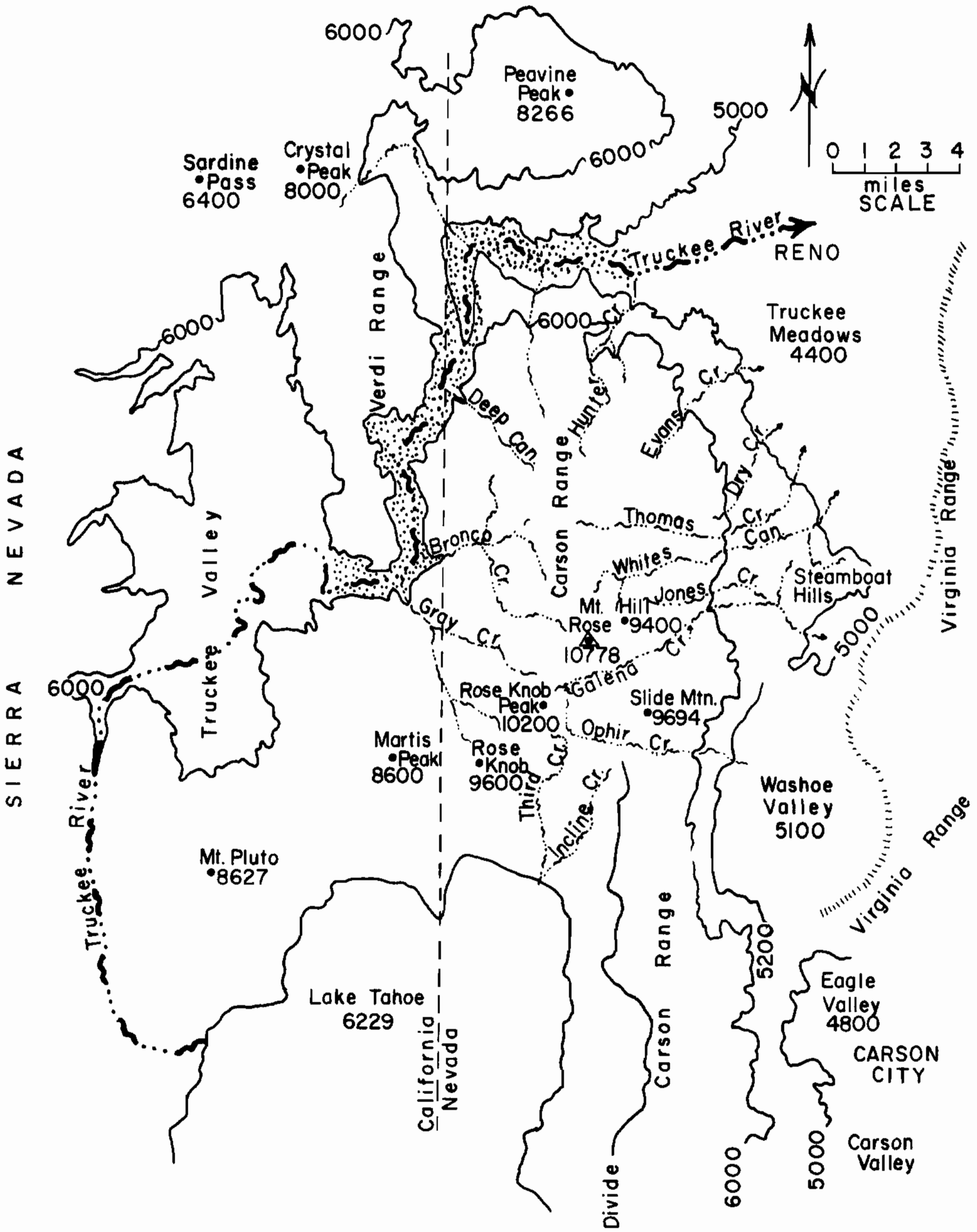

Figure 2. The present drainage pattern of the Truckee River area. Truckee River Canyon is shown by stippling.

Truckee River Canyon just south of Peavine Peak is older than Lousetown flows in the canyon. Lake overflow does not appear probable. Sardine Pass (Fig. 2), elevation 6400 ft, about 10 mi north of Boca Reservoir west of the Verdi Range, may obviate such an interpretation.

I suggest an explanation based on normal stream development without postandesite uplift. Minor north-trending faults cut the andesite of the range (*see* Thompson and White, 1964, Pl. 1; Burnett and Jennings, 1962; and *compare* Lindgren, 1897), and some of them are tectonic. Other faults may be partly the result of compaction or slumping of the thick sequence of andesitic pyroclastic rocks over buried rough topography and need not have been essential elements in the structural relief of the infravolcanic basement (Lindgren, 1897; Lovejoy, 1968). Such intense deformation is beautifully illustrated in the Chalk Hills of the Virginia Range (Thompson, 1956). The faults may have localized parts of the drainage. Thus, I hypothesize relatively little range uplift subsequent to volcanic deposition and suggest that stream development was primarily due to erosion consequent on the volcanic rocks.

There are two closely related possibilities for the development of the drainage system. First, and less likely, the lake did not overflow, but was drained after headward erosion cut its way from the east side (elevation <4400 ft) of the range across the divide and into the eastern shoreline (elevation 6400 ft or more).

Second, and more likely, the lake in Truckee Valley may originally have overflowed to the north through Sardine Pass and into the Feather River. This river incised the Truckee Valley strata to an elevation of 6,400 ft. Headward erosion by east-flowing consequent streams in Truckee Meadows cut westward across the range divide (Fig. 3) and captured the north-flowing river. Insofar as the process under discussion is concerned, either of these possibilities would result in a nonantecedent crossing of the Carson Range by Truckee River.

Streams in the northern Carson Range (Fig. 2) flow east, west, or north into the Truckee River, probably originally consequent on the Lousetown basalt. Others flow radially from the Hill 9400 volcano. For example, Deep Canyon flows northwest, Hunter Creek flows

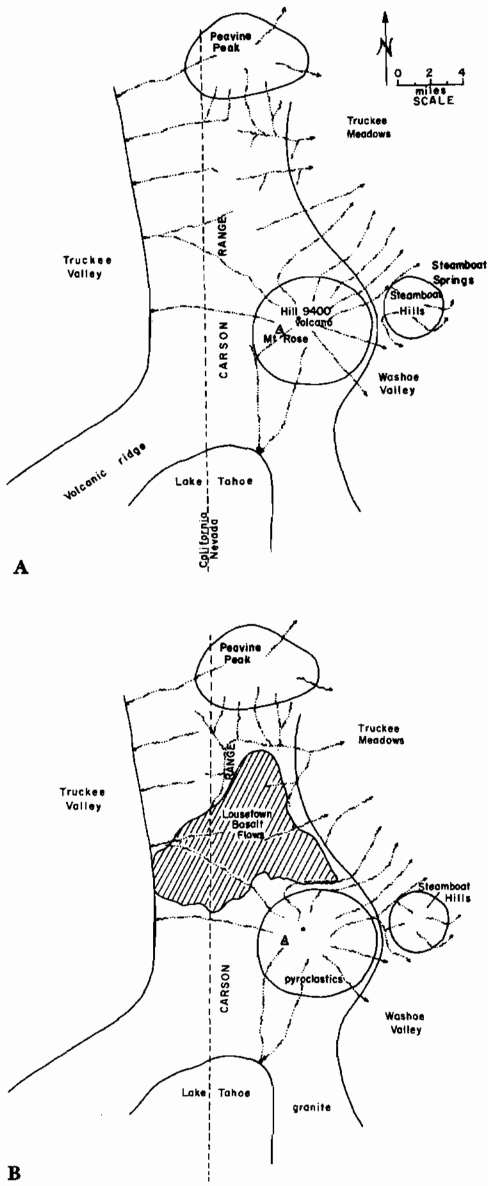

Figure 3A. Pre-Lousetown–post-Kate Peak Formations' drainage pattern, late Pliocene or early Pleistocene. B. Effect of Lousetown basalt stones and consequent drainage. C. Headward erosion by the Truckee River and its tributaries, fed by the consequent run-off on the Lousetown basalt stones. D. Headward erosion by obsequent stream development in the western walls of the upper Truckee River Canyon. E. Breaking of western wall of upper Truckee River Canyon and drainage of Truckee River Valley through the Carson Range. F. Present-day drainage pattern.

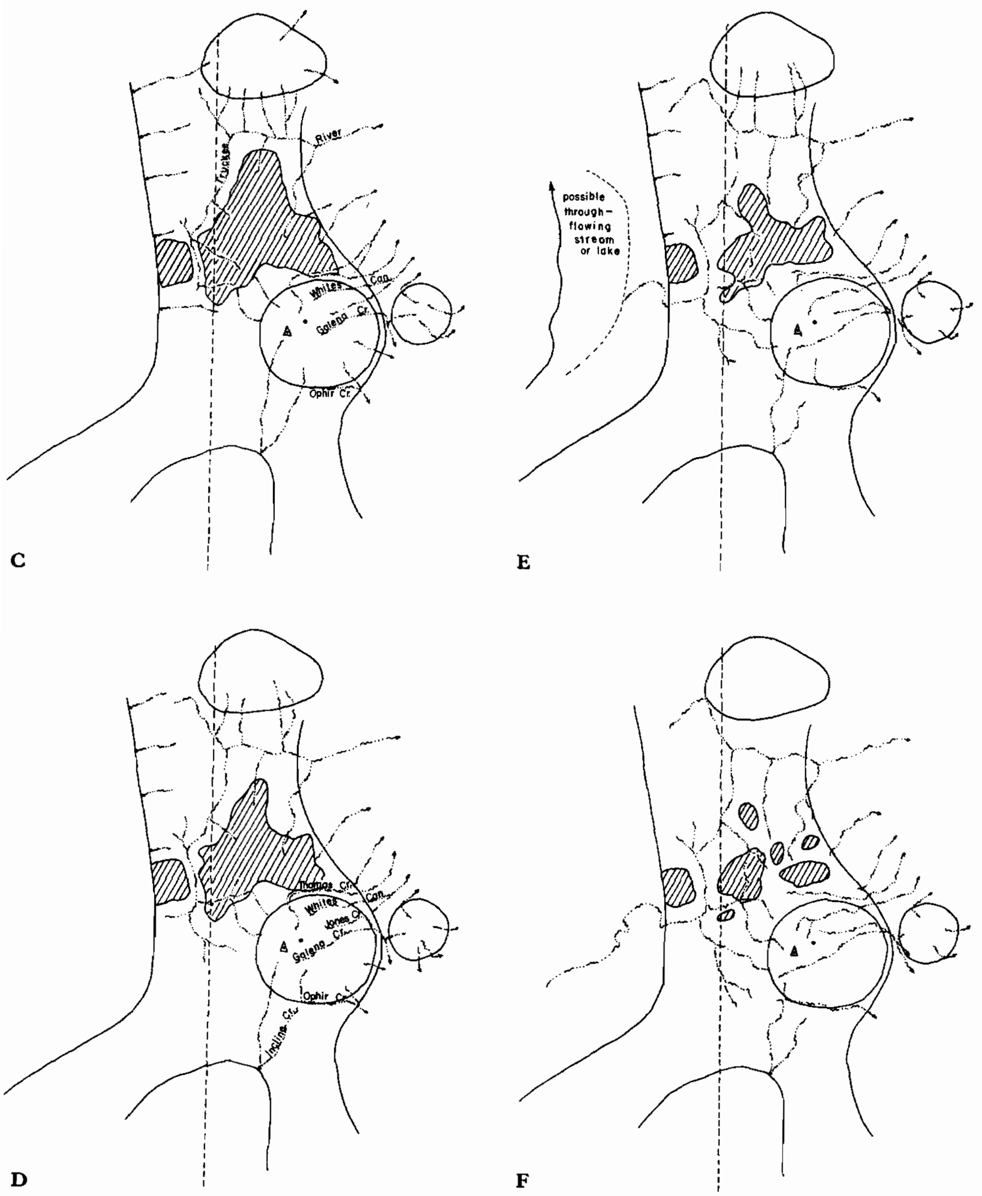

Figure 3. (Continued)

north, and Alum and Evans Creeks flow northeast.

Streams flowing from near Mount Rose show a pattern perhaps inherited from that volcano. In its heights the volcano was probably a symmetrical composite cone, but at its base it surmounted an elongate range with drainage to the east and west. Thus, streams descending from the cone may have been radially directed, but lower streams may have flowed parallel off the flanks of the range. Thus, Thomas, Whites, and Galena Creeks have a radial angular spread of about 60° (Fig. 2). The headward reaches of Ophir Creek south of Slide Mountain bend 90° west of Slide Mountain, and the upper reaches of Whites Creek bend 90° north of Hill 9400, the throat of the volcano. Galena Creek cuts granodiorite south of Mount Rose, emerging into Kate Peak volcanic rocks east of Mount Rose. Thus, upper Galena Creek has been superimposed on granodiorite from Kate Peak Formation. Even upper Whites and Thomas Creeks head in volcanic rocks, cross granodiorite in deep canyons, and continue in their lower courses through the pyroclastic rocks. Obviously, those streams were superimposed on the granodiorite from the pyroclastic rocks.

It is especially noteworthy that Galena and Ophir Creeks developed transverse drainages across the Carson Range, heading in that range, but not flowing through it, as does the Truckee River. This clearly demonstrates the efficacy of headward erosion by east-flowing consequent streams, the principal mechanism here suggested for the course of the Truckee River through the range.

GENESIS OF TRUCKEE RIVER CANYON

Peavine Peak is composed of Sierran intrusive and metamorphic rocks, and is flanked low on its southern side by pyroclastic rocks and some lake sediments. In contrast, the Carson Range southeast of Truckee River consists of thick pyroclastic rocks on granite, the tops of which slope gently northward from Slide Mountain and are barely exposed in Truckee Canyon between the north end of the range and Peavine Mountain. Thus, Peavine Peak may represent one of the following: (1) a block upfaulted higher than the Carson Range south of the Truckee River, prior to volcanic deposition; (2) a block upfaulted in postandesite time; (3) a mass of erosionally resistant granitic and metamorphic rocks which stood at a higher level during deposition of the Kate Peak pyroclastic rocks which lapped up on its south flank. This hypothesis favors (3); I have found no structural evidence which favors (2) and hypothesis (1) is, for present purposes, equal to hypothesis (3).

The pyroclastic rocks from the Hill 9400 volcano cascaded as lahars and flows (Curtis, 1954) over the ancestral basement block to form a thick sheet which lapped up on the southern flanks of Peavine Peak. Southeast-flowing streams on the south slope of Peavine Peak and northeast-flowing consequent streams from the north slope of the Carson Range met in the asymmetrical depression to form a major east-flowing stream. This stream, flowing into the lower Truckee Meadows (Fig. 2) eroded more rapidly than did those flowing west into Truckee Valley, hence the drainage divide migrated west, anchored at the north by Peavine Peak, and at the south by the volcano. At the same time, stream dissection began to work headward north into Peavine Peak and south and west into the pyroclastic rocks of the Carson Range. Headward erosion in the metamorphic rocks was slow and in the pyroclastic rocks was fast: the divide migrated west and south.

With divide migration southward, northwestward-flowing streams from the volcano were beheaded; thus the more southerly streams of this drainage net gradually became larger, incorporated drainage basins of higher elevations, and eroded into more readily erodible rock than did the drainages on the north side of the system on Peavine Peak. Lousetown basalt flowed down the mountain at this time. North-south faults may have guided the development of the north-flowing river reach. Original north-striking planar flow layers also may have aided in rectifying the channel by homoclinal shifting. In due time the Lousetown basalt flows at Bronco Creek were cut by headward erosion; farther north flows of similar age had cascaded down into the river valley and appear younger than the canyon. This rapid headward erosion proceeded southward and westward until the obsequent streams, draining eastward on the west flanks of the major north-trending ancestral Truckee River Canyon, began to erode headward into the pyroclastics of the west flank of the range. One of these obsequent streams, guided by the capture of major streams coming directly from the volcano, finally cut into the drainage system of Truckee Valley, and the crossing of the Carson Range was achieved.

ANALYSIS

The development of Truckee River Canyon (Figs. 3A–3F) is described in six steps as follows:

A. Pre-Lousetown–post-Kate Peak Formations' drainage (Thompson and White, 1964) was essentially radial from the Hill 9400 volcano, probably consequent on all the volcanic rocks, older and modified by structure on the granitic core mainly south of the volcano, and locally guided by varying lithologies and the many minor faults in the areas (Fig. 3A).

B. The Lousetown basalt flowed out onto the Carson Range surface, flowed down into the valley at the north end (Thompson and White, 1964), but flowed westward down the slope of the range into Truckee Valley south of the Canyon near present-day Bronco Creek (Birkeland, 1963, Fig. 4). The radial drainage pattern on the north side of Hill 9400 volcano was disrupted, and a consequent drainage developed on the Lousetown basalt. Minor ponding of drainages produced local small lakes above some of the flows. The lake sediments in some of these lakes were subsequently covered by younger flows (Fig. 3B).

C. Headward erosion southward and associated stream captures of the northwestward-flowing streams were started by the Truckee River and its tributaries. The Truckee River Canyon was cut through the thin basalt flows which lay on readily erodible pyroclastics of great thickness and is younger than the Lousetown flows, as Birkeland (1962) pointed out, yet older than the Lousetown flows farther north, as Thompson (1964) pointed out. No postrange uplift is needed to explain the cutting of the Lousetown flows at this point.

Modification of the original radial drainage from Steamboat Hills and the east side of the Hill 9400 volcano was the result of a steeper gradient to the southeast into Washoe Valley where the frontal scarp at Slide Mountain is very steep. Galena Creek, and then Jones Creek were pirated and diverted to the southeast (Fig. 3C). Compare this stage of development with that shown by Birkeland (1963, p. 1457, Fig. 4, and p. 1461–1462).

D. Headward erosion by obsequent stream development in the western walls of the upper Truckee River Canyon, formed of erodible pyroclastic rocks, proceeded rapidly as the canyon deepened with the increased run-off from the northwestern side of the volcano. Dissection of the thin Lousetown basalt flows also proceeded rapidly. Drainage development on the south and west flanks of the volcano consisted of stream capture of the upper reaches of Incline Creek by Ophir Creek and continuing rapid headward erosion into the pyroclastics around the volcano by Galena Creek. Early Pleistocene glaciation in the upper reaches of Galena Creek may have aided the headward erosion of this canyon much more than it did any other canyon in the range (Fig. 3D).

E. Finally, one obsequent stream managed to breach the western wall of the upper Truckee River Canyon and enter the soft strata of Truckee Valley. Irrespective of the presence of a lake, once this event occurred it was but a matter of time before the drainage of Truckee Valley through the Carson Range was accomplished. Whether a lake existed here, as thought by Lindgren, or a playa, or a northward-flowing river system, the development of a through-flowing Truckee River system followed breaching of the western rim of the Truckee River Canyon wall. Inasmuch as lake sediments younger than the Lousetown flows have not been found in the region at any elevation near that required by Lindgren's hypothesis, there seems little probability that lake overflow was the mechanism by which the Truckee River crossed the Carson Range. Nevertheless, to the extent that both theories are predicated on a stable range, the results are the same insofar as tectonics are concerned.

On the south side of the volcano, Ophir Creek has finally beheaded Incline Creek, Galena Creek has worked west of the volcano, by glaciation to a great extent, and the Lousetown basalts have been greatly dissected.

F. The present drainage pattern (Fig. 3F).

Several points pertaining to this hypothesis should be explained. First, headward erosion is a process which very definitely has proceeded actively in the Carson Range, not only radially from Hill 9400 volcano, but also to the south in the great volcanic pile at Markleeville where the Carson River has integrated its drainage through the volcanic and plutonic assemblage by just such a process. Headward erosion has caused scarp retreat of many miles at Mesa Verde, Colorado, of the High Plateaus in Utah, and of volcanic rock assemblages in the Big Bend and Jeff Davis Mountains of west Texas, as well as many other parts of the world. The only problem concerns rates of headward erosion, not the process or its efficacy. The rates are definitely demonstrated by the drainage around Mount Rose where there has resulted superposition of range-crossing, east-flowing, originally consequent streams, since the formation of the volcano at Hill 9400 in early Pliocene time.

Second, the steeper gradients on the east side of the range compared to those on the west are not sufficient to prove greater headward erosion by streams on the east side. Obviously, windward slope catchment on the west side, and northwestern slope snow accumulations during early Pleistocene cooler and wetter climates must also have been important. Thus, during the early stages of headward erosion there may have been only a slightly greater advantage for the steeper streams on the east. But once those streams had gotten to a point where they could capture northwestward-flowing streams they achieved a major advantage and this, coupled with the greater gradient, enabled them to erode headward far more rapidly than the streams on the west.

Birkeland (1968, p. 472) is correct when he states that the Carson Range was "present in approximately [its] present position during the deposition of the Truckee Formation." Evidence that the pyroclastic rocks were dumped rapidly in huge volumes on a rugged relief of thousands of feet has been given (Lindgren, 1897; Lovejoy, 1969). Therefore, the outward dips of the pyroclastic rocks and water-laid tuff can also be partly explained as the result of original deposition on the flanks, in places quite steep, of the range from the volcanic source in its heights. Also, compaction of the thicker tuff sequence which accumulated in the valley would also produce higher dips toward the basins. Sliding of water-laid beds to produce vertical dips occurs in the same formation in an otherwise unfolded area in the Chalk Hills of the Virginia Range to the east. The fault pattern along the east side of the Carson Range suggests major strike slip. Steepening of dips, such as that which produces isoclinal folds in the San Andreas fault, is probable.

Thus, the 30° dips in the Truckee beds on the east side of the Carson Range do not prove post-andesite uplift of the range any more than does the cutting of the Lousetown flows by the Truckee River. There may have been post-andesite range uplift, but evidence other than this is needed to prove it.

SUMMARY AND CONCLUSIONS

The Kate Peak pyroclastic rocks were deposited rapidly and in great volume on a range with a rugged relief of thousands of feet. Present dips of agglomerate beds on the heights and fast water-laid tuff beds on the flanks can be due to original deposition with steepening caused by differential compaction and sliding, and strike slip on the range border fault. Thus, the dips of the tuff in Truckee Meadows are not prima facie evidence of range uplift or regional folding.

Major streams in the range near Mount Rose head west of the general divide, have evidence of capture, and show that the process of headward erosion can result in streams which cross the general divide and now cut deeply into granite following superposition from pyroclastic rocks. A stream system cutting mostly pyroclastic rocks could have worked headward more rapidly across the main divide, and by a normal procedure could have captured streams from Truckee Valley.

That the river cuts the Lousetown Formation does not constitute proof of antecedence or upwarping. Headward erosion across those flows could have produced the same relationship.

Therefore, the major conclusion of this paper is that Truckee River may not be evidence of range uplift, either by faulting or warping, or antecedence.

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