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Paleozoic Sequences and Thrust Slices of the Seetoya Mountains, Independence Range, Elko County, Nevada

Abstract: Three stratigraphic sequences of lower Paleozoic rocks in the Seetoya Mountains east of Tuscarora, Nevada, are of partly equivalent age. The highest sequence is Lower Silurian and younger, composed of bedded cherts, quartzite, volcanic rocks, and graptolitic shales, deposited in a western eugeosynclinal belt, and thrust southward or southeastward for some scores of miles. Each of two lower sequences includes the same five Ordovician and Silurian formations which differ markedly in thickness and slightly in lithology. They are predominantly carbonate rocks with some quartz sandstones, deposited in an eastern miogeosynclinal belt. The upper of these latter sequences has been thrust about 6 miles southward or southeastward.

The eastern sequences were folded, faulted, and eroded, probably in pre-Carboniferous or Permian time. Siltstones, laid unconformably on the southern of the two eastern sequences, may have been derived from rising lands in the eugeosynclinal belt. Thrusting of uncertain age carried a thick plate of allochthonous rock of the western belt southerly or southeasterly. Presence of younger rocks beneath the thrust in the south suggests that there was a regional southward slope at this time. A second thrust, which developed within the eastern belt, carried parautochthonous rocks and may be a subsidiary thrust initiated by movement of the overriding rocks of the western belt. This thrust shows a close similarity to the peel thrusts of the Western Alps. Block faulting during Tertiary is largely responsible for the present-day north-south trend of the range.

CONTENTS

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INTRODUCTION

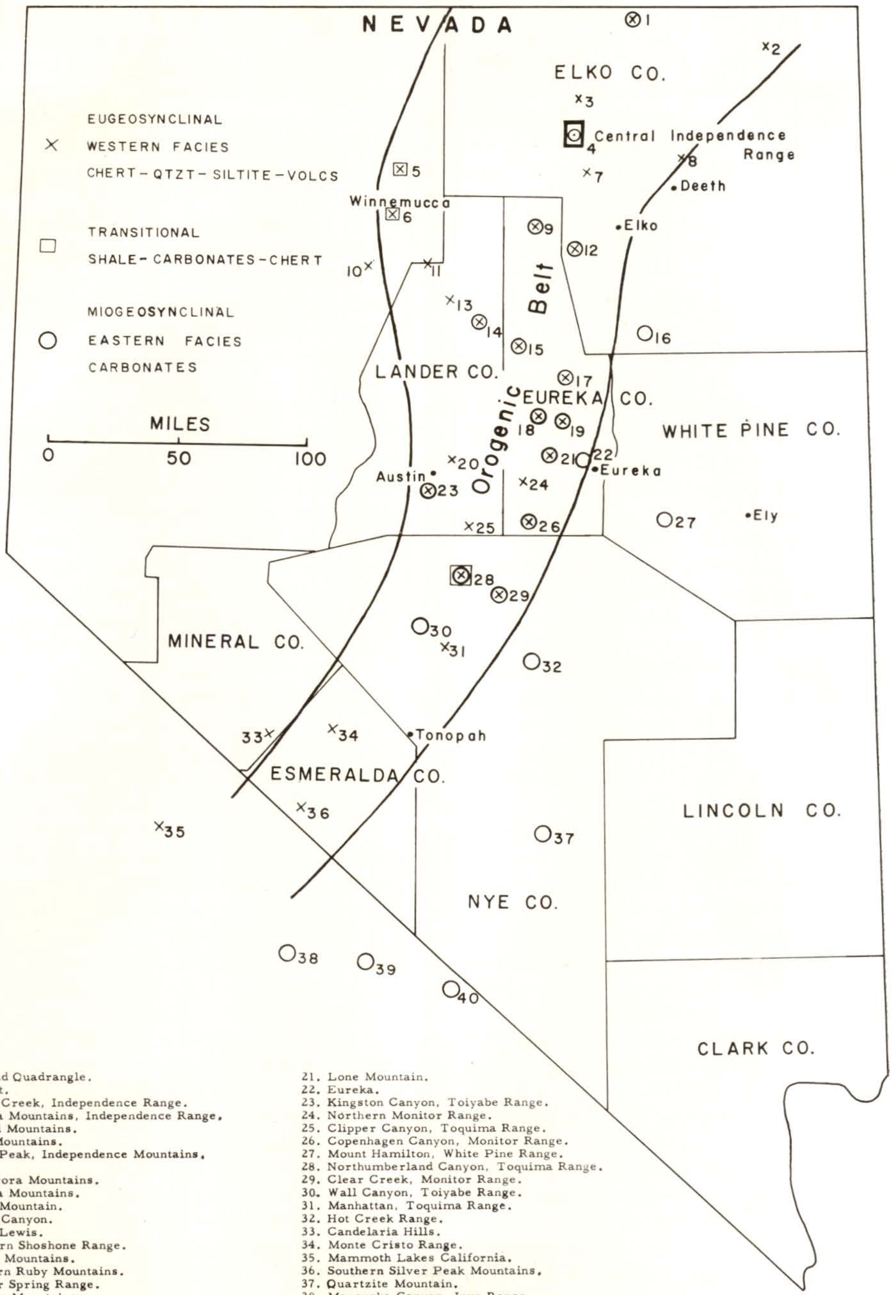
SCOPE OF THE PROBLEM: The State of Nevada lies within the Cordilleran geosyncline, and throughout much of Paleozoic and Mesozoic time has been the site of deposition of great thicknesses of rocks. Lateral facies differences over broad areas and large-scale low-angle thrust faults have complicated the unravelling of the interrelations.

Figure 1, adapted mainly from J. P. Crawford (1958, Ph. D. thesis, Columbia Univ., p. 59, Fig. 1) and Roberts and others (1958, p. 2822, Fig. 4), shows the regional distribution of the Ordovician rocks in Nevada. West of a curving line which trends north-northeast–south-southwest through the state, all Lower Paleozoic rocks are of eugeosynclinal type and of the western assemblage. Within the Antler orogenic belt, which trends northeasterly through the central part of the state, rocks of the western assemblage have been thrust scores of miles easterly or southeasterly. In the eastern part of the orogenic belt they rest upon miogeosynclinal rocks of the eastern assemblage, which were deposited in the Millard belt (Kay, 1947). In the western part they rest upon rocks of a transitional zone between the eastern and western types, called the Roberts Line (Kay, 1956). The eastern boundary of the Antler orogenic belt (R. J. Roberts, 1949, Geology of the Antler Peak quadrangle, Nevada, U. S. Geol. Survey Open-File Rept., p. 95) is drawn through the easternmost exposures of western assemblage rocks. Since the days of the early surveys it has been known that the Lower Paleozoic rocks of western Nevada are in large part clastic rocks, shales, sandstones and cherts, in contrast with a dominantly carbonate sequence of the eastern part of the state. Kirk (1933) suspected that a major thrust might have carried the western-type rocks eastward; in 1942 Merriam and Anderson discovered and named the Roberts Mountains thrust. A major thrust surface, upon which rocks of the western belt have moved eastward, has been referred to as the Roberts Mountains thrust; it developed between Late Devonian and Late Mississippian. This was a part of the Antler orogeny, which continued into Pennsylvanian (Roberts and others, 1958, p. 2850). The Seetoya thrust in the Independence Range is structurally the same as the Roberts Mountains thrust, and may correlate with latest Roberts Mountains thrusting; however it is probably younger. Possible correlatives are the late Permian thrust in the Golconda quadrangle (Roberts, personal communication, 1960), Jurassic thrusting of the Hawthorne and Tonopah quadrangles (Ferguson and Muller, 1949), Cretaceous thrusting of the Jackson Mountains (Willden, 1958), and Tertiary thrusting of the Gold Hill area (Nolan, 1935, p. 177). Thrusting in the Independence Range need not correlate precisely with orogeny elsewhere. It is becoming increasingly evident (Nolan, 1935; Roberts and others, 1958) that orogenic movements and thrusting in the Great Basin are due to episodes in a long epoch of crustal activity that affected areas spasmodically.

For some time it was believed (Nolan and others, 1956, p. 23) that a low-lying land barrier formed two separate seaways, carbonates being deposited in the eastern one, and a chert, slate, and quartzite sequence in the western one. Some rock units that are thick in the central Millard Belt thin or disappear as they approach the western margin (Kay, 1955). Kay (1955) and Crawford (1958) in the Toquima Range, and Roberts and others (1958) in the Edna and Osgood Mountains have described Ordovician assemblages that contain elements of both the eastern and western facies. This indicates that the eastern and western facies interfinger along a zone trending northeasterly through central Nevada; this zone is called the Roberts Line (Kay, 1956).

Pre-orogenic clastic rocks were shed east and west from uplands which rose in the eugeosynclinal belt in the Late Devonian or Early Mississippian; they were the forerunners of the Antler orogeny (Roberts and others, 1958) and were overridden by the Roberts Mountains thrust. Deposition of an extensive wedge of clastic rocks (Dott, 1955; Roberts and others, 1958) followed thrusting. This has been called the overlap assemblage, and its basal beds vary in age from place to place. Late Paleozoic or Mesozoic clastic rocks predate the Seetoya thrusting in the Independence Range. They may be correlative with the pre-orogenic clastic rocks of Roberts and others, in which case the Seetoya thrust would probably correlate with the Roberts Mountains thrust. If they correlate with the post-orogenic clastics, then the Seetoya thrust is later than the Roberts Mountains thrusting. These rocks may, however, be more closely associated with Mesozoic thrusts, being a flysch deposit predating them, in the early stages of orogeny.

LOCATION AND ACCESS: The Seetoya Mountains are in the central part of the Independence



1. Rowland Quadrangle.
2. Contact.
3. Marsh Creek, Independence Range.
4. Seetoya Mountains, Independence Range.
5. Osgood Mountains.
6. Edna Mountains.
7. Nanny Peak, Independence Mountains.
8. Deeth.
9. Tuscarora Mountains.
10. Sonoma Mountains.
11. Battle Mountain.
12. Carlin Canyon.
13. Mount Lewis.
14. Northern Shoshone Range.
15. Cortez Mountains.
16. Southern Ruby Mountains.
17. Sulphur Spring Range.
18. Roberts Mountains.
19. Tyrone Gap.
20. Mount Callahan.
21. Lone Mountain.
22. Eureka.
23. Kingston Canyon, Toiyabe Range.
24. Northern Monitor Range.
25. Clipper Canyon, Toquima Range.
26. Copenhagen Canyon, Monitor Range.
27. Mount Hamilton, White Pine Range.
28. Northumberland Canyon, Toquima Range.
29. Clear Creek, Monitor Range.
30. Wall Canyon, Toiyabe Range.
31. Manhattan, Toquima Range.
32. Hot Creek Range.
33. Candelaria Hills.
34. Monte Cristo Range.
35. Mammoth Lakes California.
36. Southern Silver Peak Mountains.
37. Quartzite Mountain.
38. Mazourka Canyon, Inyo Range.
39. Northern Panamint Range.
40. Amargosa Range.

Figure 1. Index map and present-day Ordovician facies distribution

Range, Elko County, northeastern Nevada (Fig. 1). King (1876) first referred to the highest point in the area (9057 feet) as Seetoya Peak; however, the latest topographic map shows it as Wheeler Mountain. On the basis of priority, the writer will refer to the peak as Seetoya Peak and to this part of the Independence Range as the Seetoya Mountains. This area (Pl. 1) is included in the report on geology and mineral resources of Elko County (Granger and others, 1957); however, this portion of their map bears little similarity to the geology.

About 40 miles northwest of Elko, Nevada State Highway 11, a paved road, traverses the southern part of the area in Taylor Canyon, and then parallels the western side in the Independence Valley. Ranchers have also built jeep trails on the range, so that the area is quite accessible.

The Independence Range, trending northerly, is in the northern part of the Basin and Range province, just south of the Snake River Plains. Streams flowing west to the Independence Valley become a part of the Owyhee River drainage system and flow northward to Idaho. Those flowing from the eastern slopes of the Range join the North Fork of the Humboldt that flows southwest to the sinks of the Great Basin.

METHODS AND TERMINOLOGY: Field maps were made upon 1:20,000 scale aerial photographs; the geology was transferred to a 1:24,000 scale enlargement of the Tuscarora quadrangle map. The eastern and southern parts of the area are not on the quadrangle maps, so triangulation provided control for the transfer of drainage and geology from the aerial photographs to the base map.

The rock-color chart distributed by the Geological Society of America was used in lithic descriptions.

Pole diagrams (Fig. 3) have been plotted and contoured on an equal area (Schmidt) net of the lower hemisphere. Point counting was done with a Spenser point counter mechanical stage.

A fence diagram (Pl. 4) illustrates structural relations. Three sections, which trend slightly east of north, are intersected at right angles by four eastward-trending sections. Datum is a horizontal plane at a 3000-foot elevation at the base of all sections. Lengths measured along the lines of section and parallel to the plane of the datum are true, as are distances measured perpendicular to this plane and parallel to the intersections of sections. Those measured in any other directions are in error. All angles in both planes of section are distorted.

Where specific outcrops have been referred to in the text, they have been given numbers on Plate 1.

ACKNOWLEDGMENTS

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STRATIGRAPHY

General Statement

In the Seetoya Mountains, three distinct sequences have been determined. The upper two are allochthonous, and by convention, the name applied to each is that of the underlying thrust. As the base of the lowest sequence is not exposed, it is considered to be autochthonous. The two structurally lowest sequences, the Smith Creek and the Burns Creek, are considered together. They include Ordovician and Silurian rocks and contain the same formations with similar fauna; however the formations in the two sequences differ slightly in thickness and in lithic details. The lithology, predominantly carbonatite with some quartz arenites, is characteristic of the miogeosyncline and indicates that they were deposited in the eastern or Millard belt (Kay, 1947, p. 1291). These sequences were probably continuous (Fig. 2) prior to the thrusting which telescoped them. The structurally highest sequence has been called the Seetoya sequence and is composed predominantly of dark chert and quartzite with minor volcanic rocks and siltstones. Shales from the lower part yield Lower Silurian graptolites. The lithology is typical of the eugeosyncline called the Fraser or western belt (Kay, 1947). There are similar rocks of

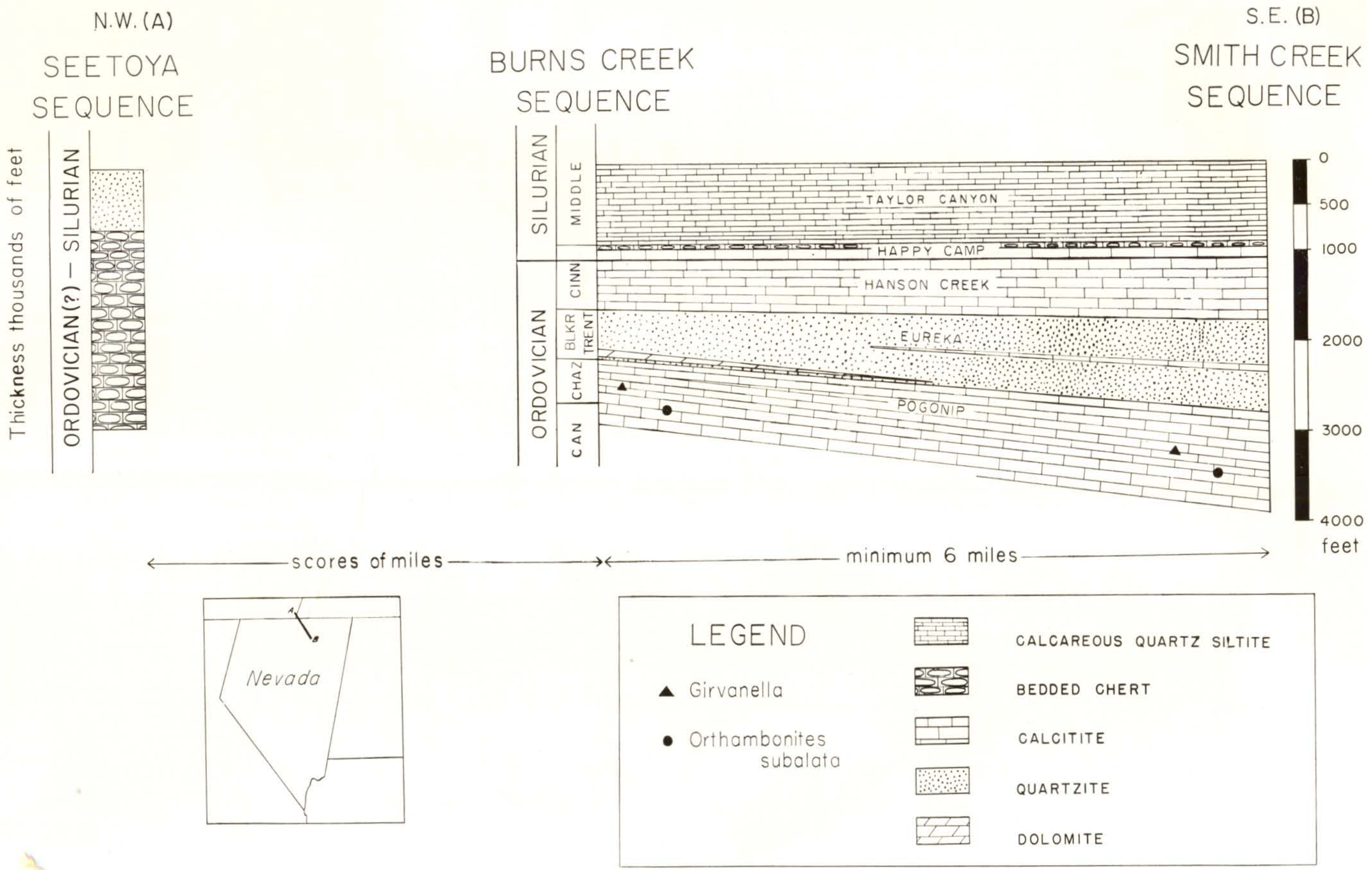

Figure 2. Restored section of Ordovician and Silurian rocks in north-central Nevada

Ordovician age farther north in the Independence Range at Marsh Creek (Kay, personal communication), and it is felt that these are a part of the same sequence. Rocks transitional between the miogeosyncline and the eugeosyncline are not present in the area. J. P. Crawford (1958, Ph. D. thesis, Columbia Univ.) and Roberts and others (1958, p. 2831) report Ordovician rocks of a transitional nature, which indicates that the two facies were deposited in contiguous basins.

Tertiary rocks in the western part of the area appear to have been deposited in a basin after the general shape of the range had been achieved. A conglomerate is overlain by a light-gray tuff, considered to correlate with Van Houten's (1956, p. 2814) vitric tuff unit of the Humboldt Formation, of late Miocene to early and middle Pliocene age.

Eastern Sequences: Smith Creek and Burns Creek Sequences

Pogonip Group. The Pogonip was originally defined by King (1878, p. 188), as a formation in central Nevada including upper Cambrian and Ordovician rocks below the Eureka Quartzite. Merriam and Anderson elevated the Pogonip to group rank (1942, p. 1683). Hintze (1952, p. 11) has recognized six formations in the group in western Utah and eastern Nevada and has proposed that it include only Ordovician rocks.

The Pogonip Group of the Smith Creek sequence is exposed only at the head of Rocky Canyon; the base is not exposed and the top is gradational with the Eureka Quartzite. One thousand and one hundred twenty-two feet of section can be seen; the lowest part is medium light-gray calcisiltite that weathers light gray, interbedded with shaly layers which weather grayish orange to dark yellowish orange. In the central part the shaly layers become less prominent and the rock is a medium dark-gray calcisiltite that weathers medium light gray. Some beds contain abundant *Orthambonites subalata* Ulrich and Cooper; a thin bed of calcisiltite is replete with *Girvanella* sp. *Receptaculites* sp. is fairly abundant at several levels. Toward the top thick bands of dolomite separate thin bands of calcisiltite; at the top the section becomes entirely dolomitic. The dolomite grades into the overlying Eureka Quartzite by increase in proportion of rounded quartz sand grains.

The Pogonip Group of the Burns Creek sequence is exposed in only one locality, just north of Burns Creek. Beneath the Eureka Quartzite lies 725 feet of predominantly dolomite rocks, the base being cut out by a thrust. The lowest exposures are composed of medium dark-gray, thin-bedded dolomite partly replaced by chert with abundant thin shaly interbeds which weather dark yellowish orange. A bed 400 feet from the top contains abundant *Orthambonites subalata* Ulrich and Cooper. Above this, the dolomite is medium dark gray and thinly interlayered with pale-red shale. Alternating with this are beds containing grayish-orange silt seams and some which contain neither. At 265 feet from the top and within the dolomite section is a 5-foot bed of dark-gray calcilutite replete with *Girvanella* sp. At 72 feet from the top the dolomite becomes light gray and medium to thick bedded; it abruptly becomes thinly laminated with quartz sand grains at the top and grades to the basal member of the overlying Eureka.

On the basis of fauna and stratigraphic position below the Eureka Quartzite, the limestones at the base of these two sequences are Pogonip and equivalent. In each section is a bed of abundant *Orthambonites subalata* Ulrich and Cooper, and above each of these is a bed of abundant *Girvanella* sp.; except for these beds both sections are remarkably barren of fossils. The corresponding fossiliferous beds could be considered as equivalent and the sections correlated even if these two distinctive fossiliferous beds are used as lithic criteria alone. The Pogonip Group is here considered Chazyan and uppermost Canadian. *Orthambonites subalata* Ulrich and Cooper is abundant near the base of both sections. This brachiopod is in Hintze's zone L in the Pogonip of western Utah and eastern Nevada (1951, p. 18) and in Ross's zone L (1951, p. 27), in the Garden City of northern Utah each of these zones being classed as basal Chazyan. The Pogonip Group of the Seetoya Mountains is considered Chazyan, at least from the lowest occurrence of *Orthambonites subalata* upward.

The two eastern sequences in the Seetoya Mountains are separated by the Burns Creek thrust. Structural evidence shows that the Burns Creek sequence has been thrust southerly a distance of at least 6 miles onto the Smith Creek sequence. The writer believes that these two Pogonip sections were laid down in a single depositional basin, separated by several miles but laterally continuous, and subsequently were thrust to their present sites so that they now lie within two superimposed structural sequences. The Pogonip in the Burns Creek sequence is dolomite, but presumably it was limestone originally, as it is in the Smith Creek sequence, and the dolomitization is due to proximity to the Burns Creek thrust. Dolomitization is general in the Burns Creek section and does not appear to be confined to stratigraphic zones.

Eureka Quartzite. The name Eureka Quartzite was proposed by Hague (1883, p. 262) for a prominent white quartzite in the Eureka area. Kirk (1933, p. 34) proposed that a better section along the west base of Lone Mountain be chosen as a new type locality. Webb (1956, 1958) made a comprehensive study of the formation in western Utah and eastern Nevada, suggesting slight revision of the latter section.

The Eureka Quartzite of the Smith Creek sequence is best exposed on the north side of the head of Rocky Canyon where it totals 1027 feet. It is composed of fine- to medium-grained quartz grains cemented by silica. A fossiliferous limestone bed within the formation separates upper and lower members which are useful in mapping. This bed is exposed only at a few places as a depression between quartzite ridges occupying a thickness interval of about 90 feet, beginning at 420 feet above the base. At the base the Eureka is gradational with the underlying Pogonip limestone, the lower few feet being dolomitic quartz sandstone, becoming more quartz sandy upward. The lower 170 feet or so is cross laminated. The quartzite is generally medium light gray to light olive gray, commonly weathering grayish orange. Thin sections show rare, well-rounded, detrital magnetite and zircon grains. The original pores have been filled by quartz cement and to a lesser degree by iron oxide (hematite) cement.

Only the middle limy member of the Eureka of the Smith Creek sequence is fossiliferous; it includes *Receptaculites* sp., *Rafinesquina* sp., and orthid brachiopods resembling *Orthambinites* sp.

In the Burns Creek sequence the Eureka is exposed north of Burns Creek. It is underlain partly by the Pogonip, but mainly it rests on the Burns Creek thrust. In the best exposure just north of Burns Creek about 2½ miles east of the Williams Ranch, the Eureka is 557 feet thick and has a dolomite member in the lower part. At the base and conformable with the Pogonip is 25 feet of medium light-gray, ledge-forming quartz sandstone which commonly has vertical worm borings and is cross-bedded. Above this is 90 feet of mainly light olive-gray, shaly dolomite weathering medium gray, with argillaceous interbeds weathering medium reddish orange. The dolomitic interval forms a terrace between the lower quartzite ledge and the overlying cliff-forming upper part of the Eureka. Fossils are abundant in the dolomite, but preservation is poor, molds and casts alone remaining. The upper quartzite of the Eureka, 440 feet thick, forms a prominent cliff of pale-yellowish-brown vitreous quartzite with fine- to medium-grained subrounded quartz sand grains cemented by silica and a little iron oxide. Detrital zircon grains are present locally. The quartzite of the Eureka here appears somewhat lighter than the corresponding quartzite of the Smith Creek sequence.

The fauna in the shaly dolomite includes *Receptaculites* sp., *Calliops strasburgensis* Ulrich and Delo, *Ampyx* sp., *Maclurites* sp., *Sowerbyella* sp., and "*Orthis*" sp.

On the basis of lithologic similarity and position in the sections, the thick quartzites of the two sequences are considered to have been laterally continuous prior to thrusting (Fig. 2). Two complete sections of the Eureka in the Smith Creek sequence are more than a mile apart, yet have slight thickness difference. At the head of Rocky Canyon the Eureka measured 1027 feet and the top is not fully exposed; just east of the Smith Creek fault in Burns Creek the thickness is 1069 feet. On the other hand, the single measured Eureka exposure in the Burns Creek sequence is 557 feet thick, and other exposures appear to be similar. Measurements in the Smith Creek sequence show that the thickness of the Eureka does not change rapidly in a single structural block. The Burns Creek sequence has been thrust southerly over the Smith Creek sequence a minimum of 6 miles. As more than 1000 feet of quartzite thins to about 500 feet, the writer suggests that the two sections were originally considerably more than 6 miles apart. The pre-Hanson Creek erosion probably did not affect appreciably the thickness of the Eureka in this area.

Webb (1958, p. 2352) gives the age of the Eureka Quartzite in eastern Nevada as Bolarian (Black River) to early Cincinnatian. It is absent in the southern Ruby Mountains (Sharp, 1942, p. 659) and the Gold Hill district of west-central Utah (Nolan, 1935, p. 16), where younger rocks rest on lower Ordovician rocks. In central eastern Nevada, Webb (1958, p. 2370) reports the Eureka to be regressive westward in the lower part and transgressive eastward in the upper part. At Antelope Valley Webb (1958, p. 2339) has measured about 600 feet of calcareous shales and siltstones with interbedded argillaceous limestones, which lies between the Pogonip and Eureka. He considers this to be the Copenhagen Formation of Merriam, a lens-shaped unit bevelled by the Eureka; it thins easterly and is partly equivalent to the lower part of the Eureka in that direction. Merriam and Anderson (1942, p. 1684–5) suggest that southward thinning of the Eureka Quartzite from Lone Mountain to the Antelope and Monitor ranges may be accounted for in part by lateral replacement of the normally arenaceous lower division of the typical Eureka by a partly calcareous facies.

The dolomitic part of the Eureka in the Burns Creek sequence is not present in the Smith Creek sequence. This dolomite is probably analagous to, and may be equivalent to, the Copenhagen Formation, the thick Eureka Quartzite thinning northward and incorporating shaly carbonates at the base. R. W. Decker (1959, unpub. rept., Nevada Bureau of Mines) assigns about 3800 feet of the Aura Formation in the Centennial Range about 25 miles north-northwest to the Ordovician, and suggests that it may correlate with the Eureka; however, faunal evidence is lacking. The Aura is mainly quartzite, phyllite, chert, and limestone; the diversity of types indicates that changes in deposition during this period were rapid. Evidence in the Seetoya Mountains indicates a northward thinning of the Eureka from the Smith Creek to the Burns Creek sequence. If the Aura Formation of the Centennial Range correlates with the Eureka of the Independence Range, then a marked increase in thickness must take place north-northwest of the Burns Creek sequence and between the two ranges.

Hanson Creek Formation. The Hanson Creek Formation was named by Merriam (1940, p. 10) for 560 feet of limestone in the Roberts Mountains. The Smith Creek sequence does not expose a continuous, undisturbed section of the Hanson Creek Formation, but a composite section of 724 feet has been measured in three segments. The two lower segments were measured on the south side of Burns Creek, 1000 yards southeast of the Williams Ranch. The lower segment is of about 300 feet of bedded calcisiltite, medium gray on fresh surfaces, commonly weathering medium light gray, and at the base weathering slightly pinkish gray. The color is probably due to alteration of fine detrital hematite seen in thin sections. The lower segment is partly replaced by beds and nodules of black chert. The middle segment is a ridge-forming, medium-dark-gray, quartz silty dolomite about 40 feet thick. The upper segment has a minimum thickness of 365 feet; it was measured in Thomas Jose Canyon about 1 mile east of Highway 11. Its lower part is not exposed; however, the thickness of omitted beds in the composite section cannot be very great. The member is dominantly dark-gray calcisiltite weathering medium light gray, in beds of 1 to 2 inches, separated by flaky, shaly layers weathering grayish orange. It is conformable with the overlying Happy Camp Formation.

The Hanson Creek Formation of the Smith Creek sequence contains *Cryptolithoides* sp., *Isotelus* sp., *Ceraurus* sp., *Streptelasma* sp., *Lepidocyclus capax* Conrad, *Climacograptus* sp., *Michelinoceras beltrami?* (Clark).

The Hanson Creek Formation of the Burns Creek sequence has a total thickness of 535 feet; exposures are poor. It was measured at the best exposure, which is above the quartzite cliffs north of Burns Creek, 2 miles east of the Williams Ranch. The formation is generally thin-bedded, medium-gray calcisiltite, weathering medium light gray, except at the base where it weathers pinkish gray. Black chert is present in thin beds and nodules.

The Hanson Creek Formation of the Burns Creek sequence contains *Cryptolithoides* sp., *Isotelus* sp., *Streptelasma* sp., *Lepidocyclus capax* Conrad, *Echinosphaerites* sp., echinoderm columnals, and a nautiloid.

The Hanson Creek Formation is correlated with the widespread carbonatite deposits of middle and upper Ordovician age that constitute one of the most persistent units of the Great Basin. This unit has been called the Fish Haven Dolomite in northeastern Utah (Richardson, 1941; Williams, 1948) and at Gold Hill (Nolan, 1935), the Ely Springs Dolomite at Pioche, Nevada (Westgate and Knopf, 1932), and the Bighorn Dolomite in the Wind River Mountains (Miller, 1930). Duncan (1956, p. 220) considers that this extensive carbonate deposit is Late, probably early Late, Ordovician; Ross (1957, p. 459) considers it to be Cincinnatian. Flower (1952, p. 25–26) clearly implies but does not definitely state that this unit is equivalent to the Trenton of eastern North America.

Happy Camp Formation. The name Happy Camp Formation is proposed for a thin formation of limestone and bedded black chert, which lies conformably above the Hanson Creek and disconformably below the Taylor Canyon formations. It is named for Happy Camp, a broad valley in the central part of the map area; the type section is in the Burns Creek sequence at the bluffs of lower Mill Creek (Pl. 2, fig. 1). Two distinct members are separated; almost invariably both are ledge-forming. Outcrops of the formation are assigned to one or the other sequence on structural evidence alone, for lithic differences between the exposures in the two sequences could not be discerned.

The best section of the Happy Camp Formation in the Smith Creek sequence is in Thomas Jose Canyon, about 1 mile east of Highway 11. Here the lower member is 108 feet of medium-light-gray calcisiltite and calcilutite which weathers very light gray. The contact with the underlying Hanson Creek Formation is conformable and was drawn where the beds change abruptly upward from a platy calcisiltite to a ledge-forming calcisiltite. At some exposures the lower part has been completely dolomitized, as in the ledges south of lower Burns Creek. The upper member is 65 feet thick in Thomas Jose Canyon, and is of alternating thinly bedded black chert and gray calcisiltite in equal amounts. Where the lower member is dolomite, the interbeds in the upper member are also dolomite. The upper member ranges from a maximum of 65 feet in Thomas Jose Canyon to a minimum of 20 feet south of lower Burns Creek. The fauna of the Happy Camp Formation is restricted to the lower carbonate member, and includes *Halysites* sp., and *Favosites* sp.

The best section of the Happy Camp Formation in the Burns Creek sequence is the type section, which is in the bluffs of lower Mill Creek (Pl. 2, fig. 1). The lower member, gradational with the Hanson Creek, is 108 feet of medium-light-gray calcisiltite and calcilutite weathering very light gray; it is commonly fucoidal and in part slightly oölitic. The upper member is 37 feet of thin- to medium-bedded black chert and gray calcisiltite, interbedded in about equal amounts; in places it is completely chertified. At locality 3 on the ledges east of Waterpipe Canyon, the upper member is 4 feet 4 inches of laminated black chert; elsewhere on these ledges the upper cherty member appears to be absent, but a contact has not actually been observed. A short distance west of Waterpipe Canyon, the upper member averages about 20 feet. A disconformity at the top of this formation accounts for the variation in thickness of the upper member, although some may have been original variation. The lower member of the Happy Camp Formation yields *Halysites* sp., *Favosites* sp., *Streptelasma* sp., and brachiopod fragments.

The Happy Camp Formation yields a meager fauna but is considered Silurian on the following evidence: It resembles the lower cherty member of the Silurian Roberts Mountains Formation of the Roberts Mountains (Merriam and Anderson, 1942, p. 1686–7) that lies in a similar stratigraphic position immediately above the Hanson Creek Formation. It strongly resembles the Diana Limestone of the Toquima Range (Marshall Kay, personal communication) which is of Silurian age. The Happy Camp Formation is disconformably overlain by the Taylor Canyon Formation which contains Middle Silurian graptolites near the base.

Taylor Canyon Formation. The name Taylor Canyon Formation is proposed here for calcareous, argillaceous quartz siltite, which rests disconformably upon the Happy Camp Formation and is unconformably overlain by the Waterpipe Canyon Formation. It was not possible to determine the original thickness, for the youngest beds are either at an unconformity, as in the Smith Creek sequence, or are overthrust by older rocks as in the Burns Creek sequence. The thickest section, 1150 feet of rocks in the Burns Creek sequence in lower Waterpipe Canyon, has been taken as the type section. This formation is pale-red to light-olive-gray, thin-bedded calcareous, argillaceous quartz siltite, weathering grayish orange. Disconnnected layers of moderate reddish-brown iron oxide produce laminae parallel to bedding; locally pyrite cubes occur. *Monograptus* sp., where present in the pale-red silty rock, is preserved as an impression or as red-brown iron oxide. Worm trails are abundant locally. The formation weathers to form subdued topography, and exposures are poor, so no detailed stratigraphic sections were measured.

The Taylor Canyon Formation of the Smith Creek sequence is exposed extensively north and west of Seetoya Peak, and there are smaller exposures farther north. It is overlain unconformably by a black siltstone eastward from the longitude of Seetoya Peak. The best exposure is on upper Smith Creek where 900 feet of rocks is preserved below the unconformity. Here the lithology is the same as that in the Burns Creek sequence, and it includes a few interbeds of medium-gray laminated argillaceous calcisiltite on the order of tens of feet thick. These do not seem continuous but are useful in local mapping and are differentiated on Plate 1.

John Riva has identified graptolites from near the base of the Storf Formation as *Monograptus* cf. *M. flemmingi* Salter, *M.* cf. *M. testis* Barrande, and *M.* cf. *M. dubius* Suess, indicating a Wenlockian or Middle Silurian age. This formation strongly resembles the thin *Monograptus*-bearing Silurian siltstones of Lovejoy (1959) at Lone Mountain, about 20 miles south in the Independence Range, and also the graptolite-bearing Roberts Mountains Formation of the Carlin window in the Tuscarora Mountains (Roberts and others, 1958, p. 2834). It is also similar to the Silurian Masket Formation of the Toquima Range (Kay, 1960). At Storf Creek in the Centennial Range, about 25 miles to the north-northwest, R. W. Decker (Unpub. rept., Nevada Bureau of Mines) has measured about 3900 feet of thin-bedded phyllites and low-rank slates with interbedded argillaceous limestones. Metamorphism has obliterated any fossils originally present, but the rocks have been tentatively assigned to the Silurian and given the name Storf Formation. These are probable correlatives of the Taylor Canyon Formation.

Waterpipe Canyon Formation. Waterpipe Canyon Formation is the name here given to late Paleozoic or Mesozoic siltstones that lie unconformably upon lower Paleozoic rocks of the Smith Creek sequence and are exposed in the upper part of Smith Creek and in the Waterpipe Canyon area. About 1 mile due east of Seetoya Peak 700 feet is preserved below the Seetoya thrust; this is a minimum thickness for the formation. The base of the formation is marked by medium-grained graywacke which contains occasional black shale and chert pebbles. A thin section shows abundant subrounded fragments of black quartz siltstone, presumably derived directly from the underlying Taylor Canyon Formation. Well-rounded quartz grains up to 0.5 mm are abundant, almost invariably being crystallographically continuous and clear, except for occasional magnetite inclusions. The matrix is predominantly black argillaceous material with abundant small subrounded quartz grains. The basal beds are well exposed around a small inlier of the Taylor Canyon Formation southwest of upper Waterpipe Canyon (Loc. 1). The remainder of the section is a monotonous sequence of platy, black argillaceous quartz siltite interbedded with occasional fine- to medium-grained graywacke similar to the basal beds.

The Waterpipe Canyon Formation was deposited on folded, high-angle-faulted, and eroded Lower Paleozoic rocks of the Smith Creek sequence; for the most part it rests upon Taylor Canyon, except in upper Waterpipe Canyon where it also lies upon the Happy Camp and Hanson Creek formations. Higher beds of the Waterpipe Canyon Formation are cut out by the overriding thrusts; they may have been partly removed by pre-thrusting erosion. This formation yielded only a portion of one undiagnostic conodont at Happy Camp (Loc. 2); rocks were partially disaggregated for the possible presence of more microfossils, to no avail.

This formation is lithologically similar to, and may correlate with, the Diamond Peak Formation of the Diamond Ranges, which Dott (1955, p. 2265–2266) discussed, and considered as correlative with the Tonka and Chainman formations. These rocks were shed eastward into the White Pine shale basin from scattered islands in the eugeosynclinal belt which were raised by orogeny and thrusting (Dott, 1955, p. 2288). They represent the forerunners of the Antler orogeny and rest unconformably upon lower Paleozoic rocks, the Chainman and Diamond Peak formations, being overridden by the upper plate of the Roberts Mountains thrust at Devils Gate, 10 miles west of Eureka (Roberts and others, 1958, p. 2850). Farther north in the Independence Range, Kay and others (1960) find Late Paleozoic rocks resting unconformably upon folded Cambrian rocks and overridden by thrusted rocks which are as young as Carboniferous. As the thrusts reported by the writer and those in the northern Independence Range reported by Kay appear to belong to the same system, the Seetoya thrust may be of Carboniferous or later age. The Waterpipe Canyon Formation predates thrusting, but owing to the present uncertainty of the dating of the thrust in the Independence Range, this helps little in the dating of the formation. The Waterpipe Canyon Formation may possibly be latest Paleozoic or Mesozoic. It is not lithologically similar to Pennsylvanian or Permian rocks of north-central Nevada (Roberts, personal communication), nor to the predominantly limestone Triassic sections reported by Clark (1957) in Elko County and the few scattered outcrops of Jurassic and Cretaceous in northern Nevada. At this time it is only certain that the Waterpipe Canyon Formation is post-Silurian and pre-Tertiary; however it may be Mississippian and equivalent to the Diamond Peak and Chainman formations.

Western Sequence: Seetoya Sequence

The Seetoya sequence is an allochthonous plate of eugeosynclinal rocks carried southerly by the Seetoya thrust. Generally it comprises the crests of ridges on the periphery of a large window that occupies most of the central portion of the map area. This window, which resulted from the erosion of the allochthonous cover, exposes the autochthonous and para-autochthonous rocks of the miogeosynclinal eastern belt.

Two members of the Seetoya sequence possess distinct lithologies and are readily distinguishable. The lower member is composed predominantly of brown to black, thin- to medium-bedded cherts which are often knobby. Locally there are interbedded, brownish, laminated quartz siltite, impure dark-gray calcisiltite, mudstones with flow casts, and dark volcanic rocks with occasional pillows. The single observed occurrence of shale (Loc. 4) is at a shaft west of lower Waterpipe Canyon. The shale is black and highly carbonaceous and contains considerable disseminated pyrite and pyrite crystals. Presence of pyritized graptolites, pyrite cubes, and the unoxidized carbonaceous material that imparts the blackness to the shales indicates an euxinic environment of deposition. Graptolites from black shales interbedded with cherts in the lower part of the Seetoya sequence in Waterpipe Canyon (Loc. 4) are Lower Silurian. In a similar sequence farther north in the Independence Range, Kay (personal communication) reports brachiopods and plant remains of Carboniferous age. These Silurian cherts may once have lain below a much thicker cover that included rocks equivalent to the younger rocks farther north. Ten samples of cherts were etched in hydrofluoric acid, with the expectation that Radiolaria would be revealed; however, none were seen. J. J. Fagan (Personal communication) states that similar chert samples from the northern Independence Range about 15 miles north have been etched, and 90 per cent of them contain abundant Radiolaria. In the lower rocks, Radiolaria would be under a thick cover and might be obliterated by recrystallization, whereas those in the higher rocks would be preserved. Bramlette (1946, p. 480) reported a similar situation in the Monterey Formation of California, in which diatoms and sponge spicules have been destroyed under great depth of burial.

The upper member of the Seetoya sequence is poorly bedded, light olive-gray to medium-gray quartzite of fine- to medium-grained subrounded quartz grains cemented by silica; considerable hematite is present along grain boundaries and may act as an additional cement. Occasional well-rounded detrital grains of zircon, tourmaline, and magnetite are present. The quartzite of the Seetoya sequence is considerably darker than the Eureka Quartzite owing to a greater amount of iron oxides and shaly material.

The two members of the Seetoya sequence are conformable; interbeds of chert occur in the basal part of the upper member and occasionally higher up. It was impossible to measure accurately the thickness of the lower member because of complex internal folding; furthermore the lower member rides upon a thrust which cuts the lowest beds. The top of the upper member is eroded; it has a minimum thickness on the order of 700 feet estimated from reconstructed cross sections.

Graptolites from a black shale in the lower part of the Seetoya sequence (Loc. 4) have been identified by John Riva as *Orthograptus* sp. and *Monograptus* cf. *M. decipiens* Tornquist, indicating correlation with the Middle to Upper Llandoverian (Lower Silurian) of Britain. Silurian rocks of the western assemblage appear to be widespread and resemble Ordovician units; recognized occurrences are listed by Roberts and others (1958, p. 2835). Silurian strata including about 4000 feet of sandstone, arkose, shale, and a little chert form part of the overrriding plate of the Roberts Mountains thrust in the northern Shoshone Range and in the Cortez Mountains. Lovejoy (1959, p. 551) reports undifferentiated chert and shale which overlies *Monograptus*-bearing siltstone at Nanny Peak. At Contact, about 75 miles to the east-northeast, Riva (1961) reports Lower to Middle Ordovician rocks overlain disconformably by uppermost Middle Silurian graptoliferous cherts, all being allochthonous and of the western facies. The Seetoya sequence is probably partially correlative with these units.

At Marsh Creek about 10 miles to the north

(Kay, personal communication), and at Nanny Peak about 20 miles to the south (Lovejoy, 1959), Ordovician graptolites occur in western-type rocks. As yet, fossiliferous Ordovician rocks of the western belt have not been found in the map area, but it is felt that the Seetoya sequence is part of a major thrust sheet containing rocks which may be as old as Ordovician.

Post-Thrust Rocks

Humboldt Formation. Rocks assigned to the Humboldt Formation are exposed in the southwest portion of the area, in the vicinity of Taylor Canyon. A conglomerate on the order of 100 feet thick, which rests unconformably on the Seetoya sequence (Loc. 5) is predominantly pebbly but contains subrounded cobbles of chert and quartzite up to 8 inches diameter. Very light-gray tuffaceous material forms interbeds in the conglomerate and, along with angular chert and quartz grains, makes up the matrix. Above this basal conglomerate lies an indeterminate thickness of predominantly light-gray to white ash and light-gray welded tuff, which makes up the bulk of the formation. Dark-green lava and quartz sandstone are interbedded with the light volcanic rocks, but since their only exposure is within a fault block, it was impossible to determine their positions. These four lithic types are differentiated on the geologic map. The Tertiary rocks are part of the Humboldt Formation (Van Houten, 1956), and the light-gray ash and tuff may be equivalent to the widespread upper Miocene to lower Pliocene "vitric tuff" unit.

Quaternary Deposits. Recent gravels and sands fill the main canyon floors and the intermontane valleys east and west of the range. Alluvial fans are not well developed for most of the streams feeding the basins are perennial.

STRUCTURAL GEOLOGY

Folds

The earliest structural event displayed in the area is the folding of the Smith Creek and Burns Creek sequences. Normal faults, such as the High Cliff fault, trend easterly parallel to the axes of folds in the Eureka Quartzite, their trend being influenced by tension joints. A north-south-trending anticline crosswise to a more distinct east-west-trending syncline (Pl. 2, fig. 2) can be seen from the head of Jack Henry Canyon. The syncline is doubly plunging as a result of the anticline crosswise to it. The poles to readings of bedding in the Eureka Quartzite of the Smith Creek sequence northwest of Happy Camp show that the main axis trends at N. 87° E. and plunges 20° E. when plotted on an equal area projection (Fig. 3C). A large fold in the Seetoya sequence north of Mill Creek is recumbent to the south. An unusual map pattern is produced by the exposure of the lower cherty member of the core through the upper quartzite member. Folds in the autochthone (Fig. 3C) that developed prior to thrusting indicate a north-south compression direction. Drag folds (Fig. 3A) and larger folds (Fig. 3B) in the allochthone indicate that the thrusting and the folding along with it took place from north to south. That these two temporally separated events occurred along similar lines supports an easterly swing in the deformed belt in the northern part of the state.

The structure of Seetoya Peak, composed of folded and faulted Eureka Quartzite, could not be determined because of poor bedding. The general structure appears to be a half dome faulted on the northwest and south, that dips quaquaversally southward and eastward. Two fold directions may also be present here.

Thrust Faults

Seetoya thrust. The Seetoya thrust was named for Seetoya Peak, which is the highest point in the area. A fine exposure may be seen in upper Waterpipe Canyon (Pl. 1, Loc. 10; Pl. 2, fig. 3), where the Seetoya sequence has been thrust directly on the Waterpipe Canyon Formation of the Smith Creek sequence. The Seetoya sequence of Fraser Belt terrane is an allochthonous plate of eugeosynclinal rocks that has been moved on the Seetoya thrust. A large window of autochthonous and parautochonous rocks makes up the central portion of the map area; its outer limits is the Seetoya thrust at the base of the allochthonous rocks of the peripheral area. The Seetoya thrust has been offset by a number of normal faults of large and small displacement; yet it can be traced almost completely around the window. The fact that the trace of the thrust in map view is oblong with some irregularities suggests that the fault plane has been domed. Lovejoy (1959, p. 558) has observed a similar situation farther south in the Independence Range. A fence diagram (Pl. 4) was constructed to show the extent of the thrusts. In detail the structure is quite complicated; when

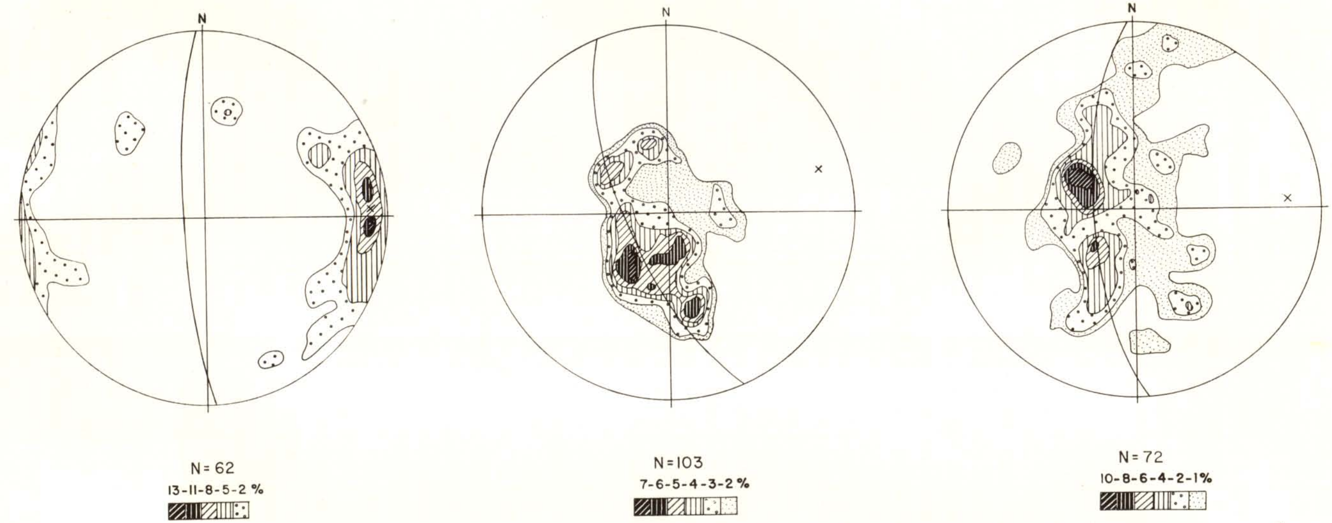

Figure 3. Point diagrams on Schmidt net, lower hemisphere. N indicates number of points; numbers below N refer to percentage values of the contours in descending order. A, Poles of axes of drag folds in chert, Seetoya sequence south and east of Waterpipe Canyon. B, Poles to bedding, Seetoya sequence north of A A′ on Plate 1. C, Poles to bedding, Eureka Quartzite in the Smith Creek Sequence north and west of Happy Camp

the rocks are separated into structural sequences (Pl. 4), the over-all picture is more easily visualized.

Burns Creek thrust. The Burns Creek thrust which underlies the Burns Creek sequence has been named for its fine exposure along the full length of the ridge north of Burns Creek (Pl. 3, figs. 1, 2). It bifurcates on this ridge to include a slice of Eureka Quartzite beneath the main thrust mass. The Seetoya and the Burns Creek thrusts are subparallel to each other on the eastern and northern sides of the main inlier, but on the western side they merge and are considered as a single thrust, the Seetoya thrust. Where separated, the two thrusts embrace the Burns Creek sequence of two parautochthonous wedges. The larger northern wedge is composed of two connected portions. The southern portion, consisting of Happy Camp Formation and basal beds of the Taylor Canyon Formation, extends from just northeast of Seetoya Peak (Loc. 11) to north of Burns Creek (Loc. 12). In this thin southward extension of the main mass of the wedge, the Burns Creek thrust follows the base of the Happy Camp Formation. North of Burns Creek (Loc. 12) the thrust cuts sharply downsection, incorporating older beds northward until it includes the complete Burns Creek sequence. Southward from the northern wedge, the Seetoya and Burns Creek thrusts merge, and the Burns Creek sequence is cut out. A small exposure of the Taylor Canyon on the south branch of Gonce Creek (Loc. 22), within the region of convergence of the two thrusts, forms a knoll atop Waterpipe Canyon beds. This outcrop is a small klippe that has been caught up along the Seetoya thrust and has come to rest upon the Waterpipe Canyon Formation; it is distinct from the small Taylor Canyon exposure (Loc. 23) which crops out in a low area and is an inlier of the Smith Creek sequence exposed below the unconformity. In a short distance the thrusts again diverge to embrace the southern wedge of the Burns Creek sequence, mainly the Happy Camp Formation and the lowermost beds of the Taylor Canyon. This wedge is thickest at its southernmost exposures in a ledge south of Waterpipe Canyon, showing the uppermost beds of the Hanson Creek, the Happy Camp, and a considerable thickness of Taylor Canyon Formations. Where last observed, the thrusts diverge toward the south, encompassing an increasingly thick section. This may continue for some distance, but it is reasonable to expect that they converge again toward the south and cut out the Burns Creek sequence. As both allochthonous sequences have their roots toward the north, they must have southern limits; the thinner Burns Creek sequence is expected to wedge out first.

The Burns Creek fault bifurcates east of the Van Norman fault, and a long, narrow sliver of Eureka Quartzite is embraced by the branches. The Eureka sliver is considered to have been shorn off and carried along at the base of the Burns Creek thrust. The thrust does not always parallel the base of the Eureka north of Burns Creek, but includes a lens of Pogonip. This lens may be a detachment from the core of an anticlinal structure, the thrust following the base of the Eureka in a syncline and traversing the higher Pogonip beds in an anticline.

Evidence of thrusting. The Seetoya thrust brought rocks of two contrasting facies into juxtaposition; that the western assemblage is allochtonous and the eastern assemblage is autochthonous is in accord with relations in much of north-central Nevada (Roberts and others, 1958). Evidence of the Seetoya thrust is as follows: (1) Early Silurian and younger rocks of the Seetoya sequence structurally override the Waterpipe Canyon Formation that lies unconformably upon the Silurian Taylor Canyon Formation. (2) Close folding is common in the rocks of the Seetoya sequence and in the incompetent rocks of the lower sequences near the thrust plane. (3) Slivers of the Happy Camp and Taylor Canyon Formations caught along the Seetoya thrust have overridden the younger Waterpipe Canyon Formation.

The Burns Creek thrust, which separates two sequences of eastern lithology, is clearly shown from the map pattern north of Burns Creek; however, parts of its southern continuation require further evidence. South of Seetoya Peak a wedge of parautochthonous rock embraced by the Burns Creek and Seetoya thrusts overrides the younger Waterpipe Canyon Formation. Consideration was given to the possibility that the map pattern is due to some combination of normal faults affecting the Smith Creek and the Seetoya sequences. To resolve the problem, two outcrop maps were prepared, and from these, two separate geologic maps drawn. One employed the hypothesis that the Burns Creek thrust underlies a parautochthonous wedge, whereas the other denied its presence. It was found

Figure 1. Happy Camp Formation in bluffs of lower Mill Creek, Burns Creek sequence

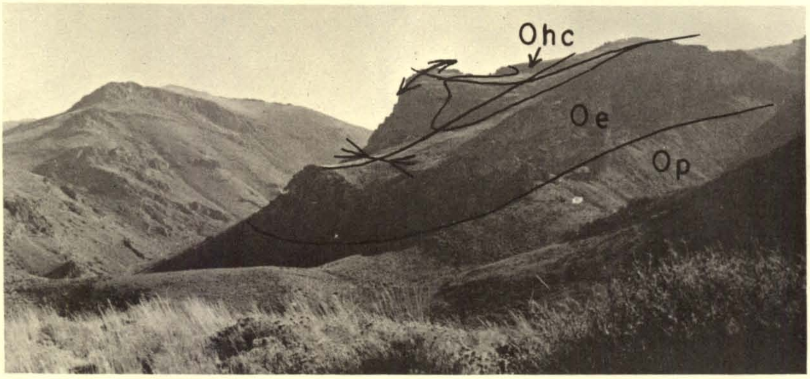

Figure 2. View looking northeast of a major east-west-trending syncline in Smith Creek sequence near Smith Creek. Double plunge in syncline in Eureka Quartzite results from north-south-trending anticline crosswise to it. Op, Pogonip Gp.; Oe, Eureka Fm.; Ohc, Hanson Creek Fm.

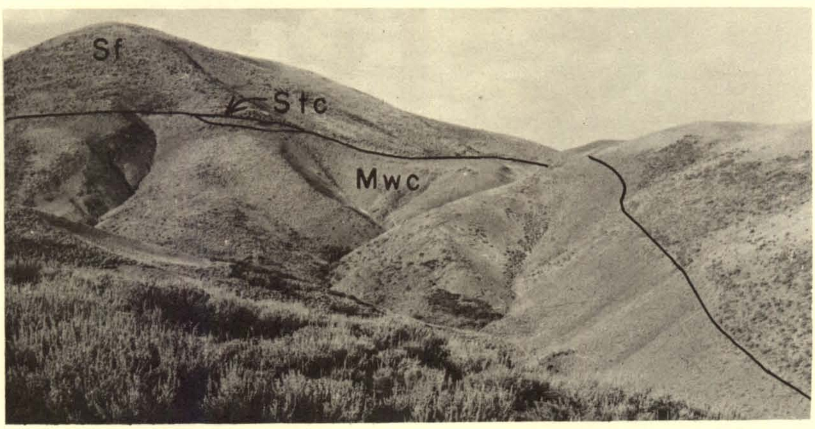

Figure 3. View of Seetoya thrust in Waterpipe Canyon, looking northward to localities 10, 11. Thrust dips east. Thin sliver of Taylor Canyon Formation of Burns Creek sequence exposed in upper left. Mwc, Waterpipe Canyon Fm.; Stc, Taylor Canyon Fm.; Sf, Seetoya sequence cherts

ROCKS AND STRUCTURES, SEETOYA MOUNTAINS, NEVADA

KERR, PLATE 3
Geological Society of America Bulletin, volume 73

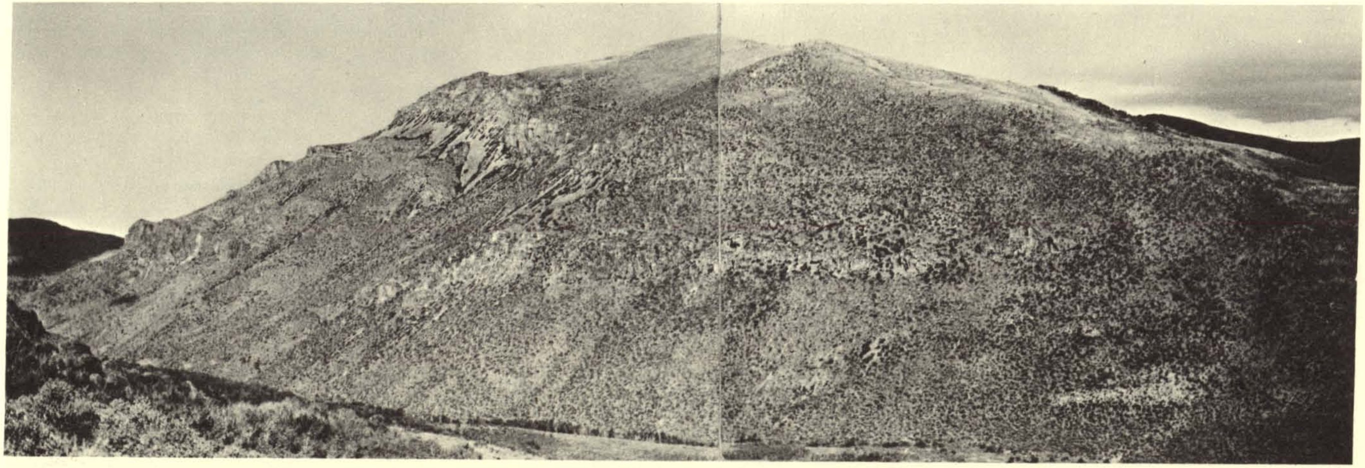

Figure 1. View looking northwest across Burns Creek showing the two eastern sequences. Burns Creek sequence overrides Smith Creek sequence; the Burns Creek thrust separates the two.

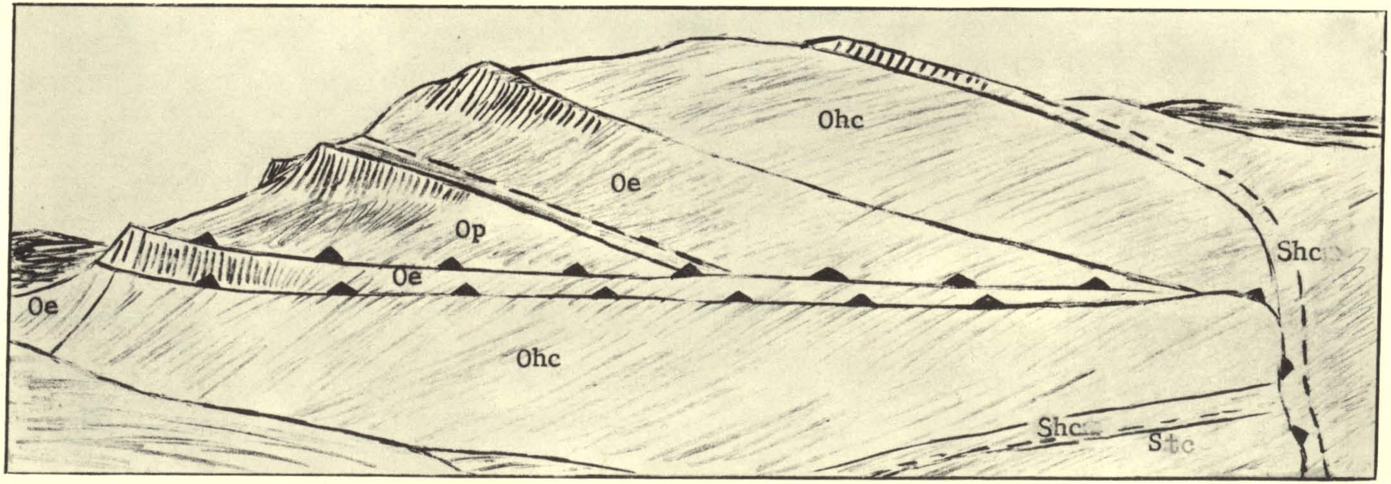

Figure 2. Diagram of Figure 1. Thrusts show barbs on upper plate.

TWO EASTERN SEQUENCES AND THE BURNS CREEK THRUST, NEVADA that the map which failed to acknowledge the presence of the Burns Creek thrust was untenable.

Strong evidence in support of the Burns Creek thrust is as follows: (1) Two sequences containing the same five formations of Ordovician and Silurian age are in juxtaposition north of Burns Creek. (2) In the Burns Creek sequence north of Burns Creek, the map pattern shows the thrust crosscutting upward through the Pogonip Group, the Eureka Quartzite, and the Hanson Creek Formation, then paralleling the base of the Happy Camp Formation (Pl. 3, figs. 1, 2). The formations of the underlying Smith Creek sequence are also truncated by this thrust. (3) Thrusting of a wedge of older rocks onto the Waterpipe Canyon Formation is the only way to explain the map pattern south of Seetoya Peak. (4) With few exceptions the attitude of the Happy Camp Formation in the southern wedge and in the southern part of the northern wedge is parallel to that of the thrust. The Burns Creek thrust is thus a bedding-plane thrust at least in its southern part. The Waterpipe Canyon therefore lies unconformably on the Taylor Canyon of the Smith Creek sequence and is overthrust by a wedge of the Burns Creek sequence. The most convincing exposures of these relationships are west of Waterpipe Canyon (Loc. 26).

The Burns Creek thrust underlies a thin southward extension of the main mass of the Burns Creek sequence from just north of Burns Creek (Loc. 12) to northeast of Seetoya Peak (Loc. 11). Although the Happy Camp and Taylor Canyon formations in the vicinity of Italian Springs have been assigned to the Burns Creek sequence, an alternate possibility is that the westernmost exposures (Locs. 19, 20) may be in fact a part of the Smith Creek sequence, and the Burns Creek thrust may lie above and eastward of where it is shown (*i.e.*, between Locs. 20 and 14; 19 and 16). The Happy Camp Formation in the western part lies above Hanson Creek in what appears to be normal stratigraphic continuity. However, the western exposures are considered a part of the Burns Creek sequence because it is possible to trace continuous exposure from certain Burns Creek rocks (Loc. 18) through the questionable exposures (Locs. 19, 20) into more of the Burns Creek sequence (Loc. 28).

Direction of thrusting. The Seetoya sequence has been thrust into the region from the north or northwest (Pl. 4, inset map). North has been determined as the most easterly probable direction. When the poles of the axes of sixty-two drag folds in cherts, which are almost entirely from the southeast part of the area, are placed on a lower hemisphere Schmidt net (Fig. 3A), they show a pronounced maximum which plunges at 10° in a direction N. 88° E. The direction of compression is perpendicular to these axes, trending from N. 2° W., the trace of the deformation plane on the lower hemisphere being drawn in on the figure. The poles to 103 readings of bedding from the cherts in the region north of *D-D'* show folds whose axes plunge at 16° in a direction of N. 72° E. when plotted on the lower hemisphere (Fig. 3B). Field observations, supported by the position of the maximum in the southern part of the diagram, indicate that folds are overturned to the south. The indicated compression direction is from N. 18° W. A western limit of northwest (Pl. 4) was chosen arbitrarily from regional considerations. The distribution of major overthrusting in Nevada (Fig. 1) shows that it has generally been in an easterly direction; Lovejoy (1959, p. 559) suggests an eastward inclination of the axial planes of small overturned folds within rocks of the western facies. Folds within the Fraser belt rocks of the Seetoya Mountains indicate thrusting from the north. R. W. Decker (1959, unpub. rept., Nevada Bureau of Mines) reports that the major folding in the Bull Run and Mountain City quadrangles has a N. 70°–80° E. grain. Riva (1961) reports thrusting in the vicinity of Contact to have been from north to south. Local variations in the direction of thrusting are not surprising, J. P. Crawford (1958, Ph. D. thesis, Columbia Univ., p. 39) reported thrusting in three directions in the Toquima Range. The regional distribution of rock types (Fig. 1) and the change from an easterly to a southerly direction of compressional forces may indicate an easterly swing in the deformed belt in the northern part of the state. The folding within the overthrust rocks indicates that locally, at least, thrusting proceeded from the north; however, it may have been from the northwest regionally.

The shape of the Burns Creek sequence suggests that the direction of movement on the Burns Creek thrust has been from north to south. The northern wedge is in two connected parts; a thin projection that includes only the Happy Camp and lowermost Taylor Canyon formations extends southerly from the main mass. An abrupt northwest increase in thickness, caused by the thrust cutting downward to include older beds, occurs along a line trending east–west north of Burns Creek. The sharp northward thickness increase and the thin southerly projection suggest southerly movement.

Distance of thrusting. The Seetoya thrust has carried eugeosynclinal sediments of the western or Fraser belt southerly or southeasterly onto miogeosynclinal sediments of the eastern or Millard belt. Figure 1, which is adapted largely from J. P. Crawford (1958, Ph. D. Thesis, Columbia Univ., Fig. 1) and Roberts and others (1958, Fig. 4), shows the present-day distribution of Ordovician rocks of these two types. The orogenic belt (Fig. 1) outlines the regions within which this thrusting occurred; its maximum width is on the order of 100 miles. The Independence Range lies within the central portion of this belt. Allochthonous rocks of this belt were carried generally easterly upon the Roberts Mountains thrust; the Seetoya thrust may or may not correlate with this thrust but involves rocks of the same two types. Displacement is of the magnitude of the Roberts Mountains thrust and is measured in scores of miles.

The displacement on the Burns Creek thrust, separating two closely similar sequences in the miogeosynclinal belt, has been considerably less than that on the Seetoya thrust. Considering the southerly direction of the movement on the Burns Creek thrust, we can estimate its minimum magnitude. As 6 miles separates the northernmost exposures of autochthonous rocks north of Burns Creek from the southernmost exposures of parautochthonous rocks south of Waterpipe Canyon, this is the minimum displacement on the Burns Creek thrust. It is felt that the displacement considerably exceeds this figure, as thicknesses of the Eureka Quartzite differ markedly between the two sequences.

Time of thrusting. The time of thrusting in the Seetoya Mountains is uncertain; it may correlate with the Late Devonian to Late Mississippian Roberts Mountains thrusting, with Permian thrusting, with Jurassic-Cretaceous thrusting, or with Late Cretaceous to early Tertiary Laramian thrusting. Unfossiliferous Waterpipe Canyon beds have been overridden by both thrusts. Although their development cannot be dated accurately, the two major thrusts of the Seetoya Mountains are believed to have been contemporaneous. They probably moved in the same direction, and there may be a genetic relationship between the two. Lower Paleozoic rocks were folded, high-angle faulted, and eroded, then overlain unconformably by the Waterpipe Canyon Formation which was also eroded. The Seetoya and Burns Creek thrusts developed later.

In the Rowland and Mount Velma quadrangles, Bushnell (1956) reports late Mississippian to early Pennsylvanian orogeny, with thrusting which probably correlates with the Roberts Mountains thrust or its equivalent. Orogeny in the Independence Range may be part of the Antler orogeny of Late Devonian to Early Pennsylvanian age, and the Seetoya thrusting may be equivalent to some part of the Roberts Mountains thrusting. This thrusting occurred not as a single movement but as several distinct pulses during the orogeny, having reached the Carlin area in Late Devonian or earliest Mississippian, and the Rowland and Mount Velma quadrangles somewhat later.

In the vicinity of Contact, about 75 miles east-northeast (Riva, 1961), post-Permian thrusts carry western-facies Ordovician-Silurian rocks southward. At North Fork Canyon in the northern Independence Range, thrusting is post-Carboniferous (Kay and others, 1960), as questionable Carboniferous rocks occur in a thrust slice, and Carboniferous or Permian rocks lie below it. The Seetoya thrust is probably equivalent to the thrusts at Contact and in the northern Independence Range and later than the thrust in the Rowland and Mount Velma quadrangles. If this is the case, the Seetoya thrust might override late Paleozoic (Permian) rocks, and it need only have small displacement in this movement, for the western allochthone was already nearby in the Rowland and Mount Velma quadrangles. Post-Carboniferous orogenic movements of considerable magnitude have been reported and are possible equivalents of the Seetoya thrust. Roberts and Silberling (Roberts, personal communication, 1960) believe that the Golconda thrust is Late Permian. In the Hawthorne and Tonopah quadrangles Ferguson and Muller (1949, p. 13) report Jurassic diastrophism with thrusts that moved generally eastward and southeastward. Late Cretaceous to early Tertiary orogeny has been reported by Willden (1958, p. 2396–7) in the Jackson Mountains about 80 miles west of the Independence Range. A thrust which Willden believes to be of relatively small displacement has brought Permian or older volcanic rocks eastward onto the

Pansy Lee Conglomerate, which is as young as Late Cretaceous or Early Tertiary. Nolan (1935, p. 177) reports long-continued orogeny marked by four or five epochs of folding or major thrusting, the more recent of the thrust epochs being Tertiary at Gold Hill. The traces of the Seetoya and Burns Creek thrusts show remarkable regularity and postdated much of the structure, including folding and some of the normal faulting of the Lower Paleozoic rocks. of the Burns Creek sequence may be analagous to the peel thrusts of the Western Alps that Bucher (1955, p. 353–355) ascribes to gravitational forces. In the peel thrusts, forces acting on the back limbs of some of the major anticlines must have sheared off layer after layer, pushing them forward essentially along bedding planes. Figure 4, taken from Bucher (1955, Fig. 6), illustrates the concept of peel thrusts. Letters mark the originally adjacent points.

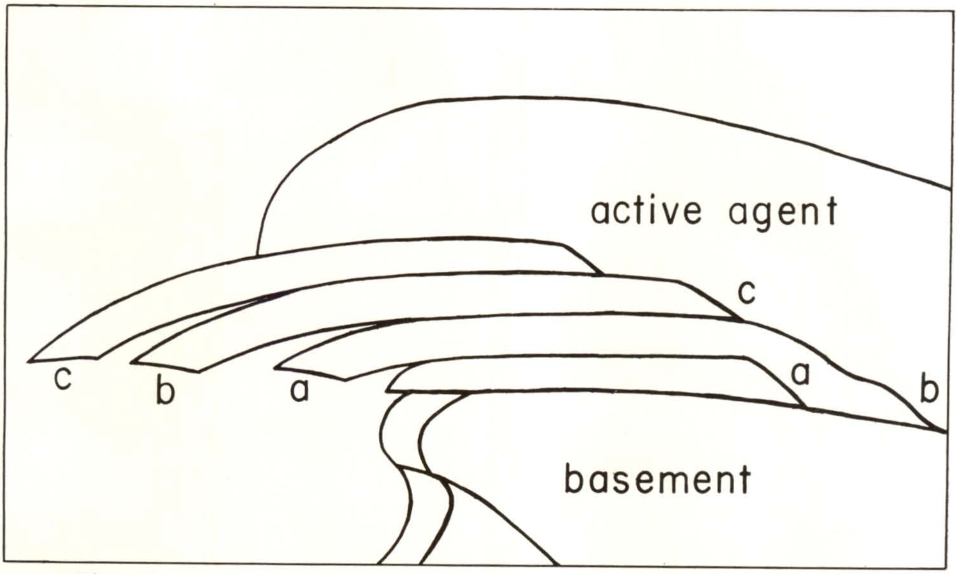

Figure 4. Diagram illustrating concept of peel thrusts (after Bucher, 1955, Fig. 6)

Mechanism of thrusting. Two initiating forces, horizontal compression and gravitational forces, have been called upon to explain thrusting of great displacement. Gravity thrusting is considered to include both movement down a slope under the direct influence of gravity and lateral flowage of a topographically high mass of rock. The following points suggest that gravity was the dominant force in the development of the thrusts of this area: (1) Complex internal folding of the Seetoya sequence suggests that the rocks were incompetent at the time of thrusting. Although they may have been many thousands of feet thick, the allochthonous rocks were scores of miles wide. Such a relatively thin, broad plate of incompetent material would be unable to transmit the necessary stresses if it were to have moved by tangential forces alone. (2) The parautochthonous northern and southern wedges The units are shown projecting into space that might be occupied by flysch sediments. The surface may have been exposed to erosion, or conceivably, may have lain below sea level. Figure 5, a diagrammatic cross section through the Seetoya Mountains at the time of thrusting, is taken north-south between sections *B-B′* and *C-C′*. This reconstruction shows a close similarity with peel thrusts; the Burns Creek sequence was probably carried along by that mechanism. An initiating force, possibly gravitational, acted upon a rising crustal fold, moving the Seetoya sequence southerly or southeasterly. The Burns Creek sequence may have been peeled off and moved along by the combined effect of a direct force on the back limbs of anticlines and frictional drag, both of which were exerted by the overriding Seetoya sequence. The Eureka Quartzite at the base of the Burns Creek sequence may be a minor peel

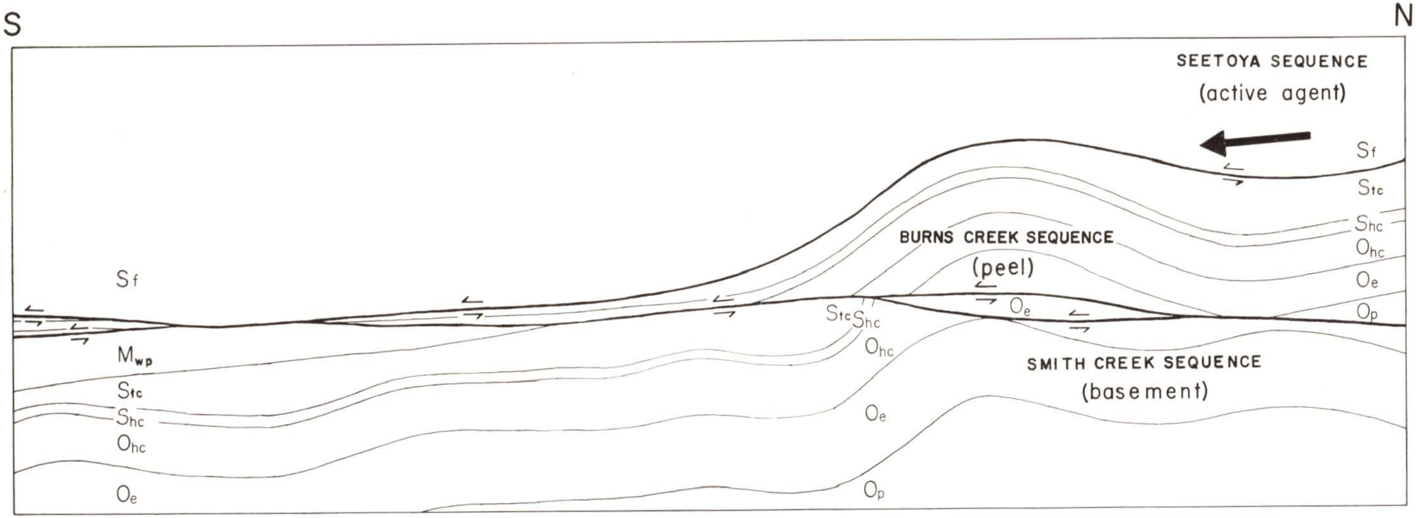

Figure 5. Diagrammatic section through the Seetoya Mountains following thrusting

thrust. The two sequences moved southerly onto the Waterpipe Canyon Formation which may be analogous to the flysch basin (Figs. 4,5). Roberts and others (1958, p. 2828–2829) consider that the Harmony sliver in Battle Mountain and other places are of similar nature to peel thrusts. (3) The Waterpipe Canyon Formation is present only on the southern part of the Smith Creek sequence. Its absence from the Burns Creek sequence and northern part of the Smith Creek sequence may indicate either nondeposition, erosion prior to thrusting, or removal by thrusting. The distribution of younger rocks below the thrust in the south points to a general regional southward slope at the time of thrusting. Movement of allochthonous and parautochthonous rock down this slope would be aided by gravitational forces.

Hubbert and Rubey (1959) have considered the role of fluid pressures in the mechanics of overthrust faulting. They conclude that, given sufficiently high fluid pressures, (1) very much longer fault blocks could be pushed over a nearly horizontal surface, and (2) blocks under their own weight could slide down very much gentler slopes. The requisite pressures do exist and are being observed in deep oil wells in various parts of the world. In the light of this hypothesis they have considered the overthrust belt of Western Wyoming and adjacent states. The thrust sheets may have slid down the western limb of the geosyncline by simple gravitation, or may have moved by regional compression. They conclude (1959, p. 167) that some combination of the two forces, pushing the wide thrust plates down a gentle slope, is the most likely explanation. High-fluid pressures may have developed in the lower part of the very thick Seetoya sequence; a general southerly slope is indicated by the distribution of the Waterpipe Canyon Formation. Perhaps these two factors were instrumental in the initiation and continuation of the great lateral movements in the Seetoya Mountains.

High-Angle Faults

Some high-angle faults in the area are considered to have preceded thrusting and the deposition of the Waterpipe Canyon siltstone. The Burns Basin fault, early movement on the Happy Camp fault, and possibly the North Boundary fault of Seetoya Peak are included in this group. Most high-angle faults occurred during the latest episode of structural deformation, probably during the Tertiary. At least some movement on the Happy Camp fault has followed both thrusts, as it cuts the Seetoya thrust (Loc. 27) and also the Van Norman fault, which in turn cuts the Burns Creek thrust. The central portion of the Happy Camp fault is parallel to bedding, but at both ends a considerable amount of the top of the Eureka is cut out; thus movement on it must be substantial. The Happy Camp fault follows thrusting, yet an offset of the Fraser belt rocks near Smith Creek (Loc. 28) was not seen; the map pattern shows a slight offset which is inferred. Two movements took place upon the Happy Camp fault, an early movement cutting out part of the Eureka, and a later movement of lesser magnitude following thrusting. The first movement was probably reverse, but the last was normal, the southeast side moving downward relative to the northwest. The Burns Basin fault extends in three broken segments from its truncation by the Van Norman fault in the valley of Smith Creek to the vicinity of Burns Basin. In the more southerly segment, the fault nearly parallels bedding on one end, cutting upsection upward on the northern end. On its northeast end the Burns Basin fault appears to be overridden by the Burns Creek and Seetoya thrusts. The traces of the Happy Camp and Burns Basin faults strongly suggest that both have an easterly dip, and the map pattern thus indicates reverse movement. These faults, particularly the Happy Camp fault, parallel bedding in places on anticlinal limbs and transect it on the crests. They are probably related genetically to the anticlines of the Smith Creek sequence, their reverse movement having occurred as a response to compressional forces during the anticline formation, a stage of the orogenic history which preceded thrusting. The North Boundary fault of Seetoya Peak has a displacement on its northeast end in excess of 1000 feet, for the Taylor Canyon and Eureka formations are adjacent, and the Eureka forms a sizable scarp. This fault might have preceded thrusting and be overlain by the Waterpipe Canyon siltstone and the two thrusts above it, for the thrusts are not offset. More likely the North Boundary fault swings sharply southeasterly on its northeastern end to become the East Boundary fault. The great quartzite mass of Seetoya Peak may be a fault-bounded block that was tilted eastward. Displacement on the South and East Boundary faults appears to die out on the southeast ends. It is significant that these faults which may have preceded thrusting (1) suggest reverse movement, (2) may be genetically related to the anticlines, (3) are subparallel to each other, and (4) trend somewhat north of east. The forces producing the anticlines and the later thrusts trended approximately perpendicular to these faults, somewhat west of north. The Van Norman and the late movement on the Happy Camp fault, both belong to the later episode but did not occur together. The continuation of the Van Norman fault beyond the Happy Camp fault remains an enigma. The Mill Creek fault, which dropped Fraser Belt rocks to a considerably lower elevation on its northwest side, has a marked southeastward bend in its map pattern in the central part, which is partly the result of topography. Brecciated zones along faults in Mill and Burns creeks stand up in relief and have northwesterly dips. A brecciated zone on the Mill Creek fault strikes N. 78° E. and dips 75° NW. where it crosses Mill Creek; that on the Williams fault strikes N. 57° E. and dips 50° NW. where it crosses Burns Creek. Two sizable springs occur along the Williams fault, and one on the Mill Creek fault. A north-south-trending normal fault parallels the west side of the range in the north part of the area; it continues well north of the limit of mapping, where it begins to trend more northeasterly. A very large spring occurs along this fault just north of where it crosses Jerrett Creek.

In the southwest part of the area near Taylor Canyon, normal faults cut both the Seetoya sequence and overlying Tertiary rocks. There appear to be two sets, one striking at about N. 45° W., the other at about N. 50°–55° E. The sets probably are contemporaneous, the rocks between them moving as blocks.

Intrusive Deformation

Northwest of Seetoya Peak (Loc. 9) a vertical dike cuts the Taylor Canyon Formation and trends at N. 130° E. A 15-foot vertical dike cutting the Happy Camp and Taylor Canyon southwest of Seetoya Peak (Loc. 7), trends at N. 112° E. and probably connects with an outcrop of similar rock farther east (Loc. 8).

TECTONIC HISTORY

The Independence Range of north-central Nevada lay within the miogeosynclinal belt and received thick sediments during the Lower Paleozoic. Sedimentation probably continued without noteworthy orogenic break until the late Devonian; Lovejoy (1959, p. 544) reports carbonates as young as upper Devonian in the autochthone, overridden by western facies rocks. Broad east-west-trending folds developed early, perhaps during the Antler orogeny; high-angle reverse faults probably developed along with these folds. After some erosion, the Waterpipe Canyon Formation, probably Late Paleozoic or Mesozoic, was deposited unconformably upon Upper Ordovician and Silurian rocks in the Seetoya Mountains. Farther north in the Independence Range, at the mouth of North Fork Canyon, Late Paleozoic rocks rest with marked unconformity on folded Cambrian sediments (Kay and others, 1960). These two units may be correlative, and part of an orogenic clastic deposit derived from lands in the western belt previous to thrusting. Eugeosynclinal rocks of the western belt have been transported scores of miles by thrusts, coming to rest upon rocks of the eastern belt. Thrusts of the Seetoya Mountains carry rocks of similar type to those carried by the Roberts Mountains thrust of the Antler orogeny (Roberts and others, 1958). They may correlate with the Late Devonian to Late Mississippian or early Pennsylvanian Roberts Mountains thrusts. More likely they developed later and may correlate with Permian thrusting, with Jurassic-Cretaceous thrusting, or with Late Cretaceous to early Tertiary Laramian thrusting. Easterly thrusting in the central part of the state becomes southeasterly to southerly directed thrusting in the northern part, indicating an easterly swing in the deformed belt in the north. A subsidiary thrust that developed within miogeosynclinal rocks beneath the major thrust of the Seetoya Mountains was of lesser magnitude and also moved southerly. This thrust may have been secondary, initiated by an active agent of overriding Fraser Belt rocks; in this respect it shows similarity to the peel thrusts of the Western Alps. The fact that the Waterpipe Canyon Formation, the youngest rocks preserved below the thrusts, is restricted to the southern part of the area suggests a general southward slope at the time of thrusting. A southward slope is further supported by the evidence that erosion reached more deeply farther north in the Independence Range, Carboniferous or Permian beds resting unconformably upon folded Cambrian rocks at the mouth of North Fork Canyon. High-angle faults trending north to northeast began to develop in the Miocene and have been intermittently active until recently. These faults are responsible for the linear northerly trending basins and ranges. At present the ranges are contributing sands and gravels to the basins by perennial and intermittent streams.

CONCLUSIONS

Two contrasting facies of Lower Paleozoic rocks have been recognized in the Seetoya Mountains. The chert-quartzite-siltite-volcanic western sequence is allochthonous and has moved southerly or southeasterly on a great thrust fault onto the authochthonous carbonate eastern sequence. Thrusts carrying similar rocks have been observed elsewhere in the state and have a displacement of scores of miles (Roberts and others, 1958).

A subsidiary thrust which developed within the carbonate facies of the eastern belt has a southerly displacement of 6 or more miles. This thrust carries a parauthochthonous sequence and is comparable to the peel thrusts of the Western Alps.

The Waterpipe Canyon siltstone was laid down unconformably upon the autochthone. It is a clastic that may be considered a preorogenic deposit.

Folding, high-angle faulting, and erosion occurred in the eastern belt prior to the deposition of the Waterpipe Canyon siltstone. The sediments were partially removed by erosion and subsequently overridden by major thrust faults. The present-day structure of the range is a result of high-angle faults which transect all earlier rocks including those of Tertiary age.

REFERENCES CITED

Bramlette, M. N., 1946, The Monterey Formation of California and the origin of its siliceous rocks: U. S. Geol. Survey Prof. Paper 212, p. 1–57

Bucher, W. H., 1955, Deformation in orogenic belts, p. 343–368 *in* Poldervaart, Arie, *Editor*, Crust of the earth: Geol. Soc. America Special Paper 62, 762 p.

Bushnell, Kent, 1956, Tectonic history of the Rowland quadrangle, northern Elko County, Nevada (Abstract): Geol. Soc. America Bull., v. 67, p. 1762–1763

Clark, D. L., 1957, Marine Triassic stratigraphy in the eastern Great Basin: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 10, p. 2192–2222

Crawford, J. P., 1958, Structure of a portion of the Northern Toquima Range, Nevada (Abstract): Geol. Soc. America Bull., v. 69, p. 1549

Dott, R. H., Jr., 1955, Pennsylvanian stratigraphy of Elko and northern Diamond ranges, northeastern Nevada: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 2211–2305

Duncan, H. M., 1956, Ordovician and Silurian coral faunas of western United States: U. S. Geol. Survey Bull. 1021-F, p. 167–193

Ferguson, H. G., and Muller, S. W., 1949, Structural geology of the Hawthorne and Tonopah quadrangles, Nevada: U. S. Geol. Survey Prof. Paper 216, p. 1–55

Ferguson, H. G., Muller, S. W., and Roberts, R. J., 1951, Geology of the Winnemucca quadrangle: U. S. Geol. Survey Quadrangle Map Ser. GQ-11

Ferguson, H. G., Roberts, R. J., and Muller, S. W., 1952, Geology of the Golconda quadrangle, Nevada: U. S. Geol. Survey Quadrangle Map Ser. GQ-15

Flower, R. H., 1952, New Ordovician cephalopods from eastern North America: Jour. Paleontology, v. 26, p. 24–59

Granger, A. E., Mendell, M. B., Simmons, G. C., and Lee, Florence, 1957, Geology and mineral resources of Elko County, Nevada: Nevada Bureau of Mines Bull. 54

Hague, A., 1883, The geology of the Eureka district (Abstract): U. S. Geol. Survey 3d Ann. Rept., 1881–1882, p. 241–288

—— 1892, Geology of the Eureka district, Nevada: U. S. Geol. Survey Mon. 20

Hintze, L. F., 1951, Lower Ordovician detailed stratigraphic sections for western Utah: Utah Geol. and Mineralog. Survey Bull. 39, p. 1–99

Hubbert, M. K., and Rubey, W. W., 1959, Role of fluid pressure in the mechanics of overthrust faulting: Geol. Soc. America Bull., v. 70, p. 115–167

Kay, Marshall, 1947, Geosynclinal nomenclature and the craton: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 1289–1293

—— 1951, North American geosynclines: Geol. Soc. America Mem. 48, 143 p.

—— 1952, Late Paleozoic orogeny in central Nevada: Geol. Soc. America Bull., v. 63, p. 1269–1270

Kay, Marshall, 1955, Paleozoic of the northern Toquima Range, Nevada (Abstract): Geol. Soc. America Bull., v. 66, p. 1582

—— 1957, Paleozoic deformation and deposition in Nevada and Utah: XX International Geol. Cong., Cong. Geol. Internac., Mexico City, 1956, sec. V, p. 485–490

—— 1960, Paleozoic continental margin in central Nevada, western United States: Internat. Geol. Cong. XXI Sess. Rept., Norden, pt. XII, p. 94–103

Kay, Marshall, Hawkins, W. H., Mihm, R. J., and Widmier, J. W., 1960, Paleozoic rocks of the Jack Creek Mountains, northern Independence Range, Elko County, Nevada (Abstract): Geol. Soc. America Bull., v. 71, p. 1900–1901

King, Clarence, 1876, Geological and topographical atlas: U. S. Geol. Explor. 40th Parallel Rept., Map IV

—— 1878, Systematic geology: U. S. Geol. Explor. 40th Parallel Rept., v. I

Kirk, Edwin, 1930, The Harding Sandstone of Colorado: Am. Jour. Sci., 5th Ser., v. 20, p. 456–466

—— 1933, The Eureka Quartzite of the Great Basin region: Am. Jour. Sci., 5th Ser., v. 26, p. 27–44

Lovejoy, Donald W., 1959, Overthrust Ordovician and the Nannie's Peak Intrusive, Lone Mountain, Elko County, Nevada: Geol. Soc. America Bull., v. 70, p. 539–564

Merriam, C. W., 1940, Devonian stratigraphy and paleontology of the Roberts Mountains region, Nevada: Geol. Soc. America Special Paper 25, 114 p.

Merriam, C. W., and Anderson, C. A., 1942, Reconnaissance survey of the Roberts Mountains, Nevada: Geol. Soc. America Bull., v. 53, p. 1675–1728

Miller, A. K., 1930, Age and correlation of the Bighorn of northwest U. S. A.: Am. Jour. Sci., Ser. 5, v. 20, p. 195–213

Nolan, T. B., 1935, The Gold Hill mining district, Utah: U. S. Geol. Survey Prof. Paper 177, 172 p.

Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U. S. Geol. Survey Prof. Paper 276, 77 p.

Richardson, G. B., 1941, Geology and mineral resources of the Randolph quadrangle, Utah-Idaho: U. S. Geol. Survey Bull. 923, 55 p.

Riva, John, 1961, Easternmost occurrence of allochthonous Ordovician-Silurian western facies in Nevada (Abstract): Geol. Soc. America Special Paper 68, 322 p.

Roberts, R. J., Hotz, P. E., Gilluly, James, and Ferguson, H. G., 1958, Paleozoic rocks of north-central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 2813–2857

Ross, R. J., Jr., 1951, Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas: Peabody Mus. Nat. History Bull. 6, Yale Univ., v. 53, p. 647–690

—— 1957, Ordovician fossils from wells in the Williston Basin, eastern Montana: U. S. Geol. Survey Bull. 1021-F, p. 167–193

Sharp, R. P., 1942, Stratigraphy and structure of the Southern Ruby Mountains, Nevada: Geol. Soc. America Bull., v. 53, p. 647–690

Van Houten, F. B., 1956, Reconnaissance of Cenozoic sedimentary rocks of Nevada: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2801–2825

Webb, G. W, 1956, Middle Ordovician detailed stratigraphic sections for Western Utah and Eastern Nevada: Utah Geol. and Mineralog. Survey Bull. 57, p. 1–77

—— 1958, Middle Ordovician stratigraphy in eastern Nevada and western Utah: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 2335–2377

Westgate, L. G., and Knopf, Adolph, 1932, Geology and ore deposits of the Pioche district, Nevada: U. S. Geol. Survey Prof. Paper 171, p. 1–79

Willden, Ronald, 1958, Cretaceous and Tertiary orogeny in the Jackson Mountains, Humboldt County, Nevada: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 2378–2398

Williams, J. S., 1948, Geology of the Paleozoic rocks, Logan quadrangle, Utah: Geol. Soc. America Bull., v. 59, p. 1121–1164

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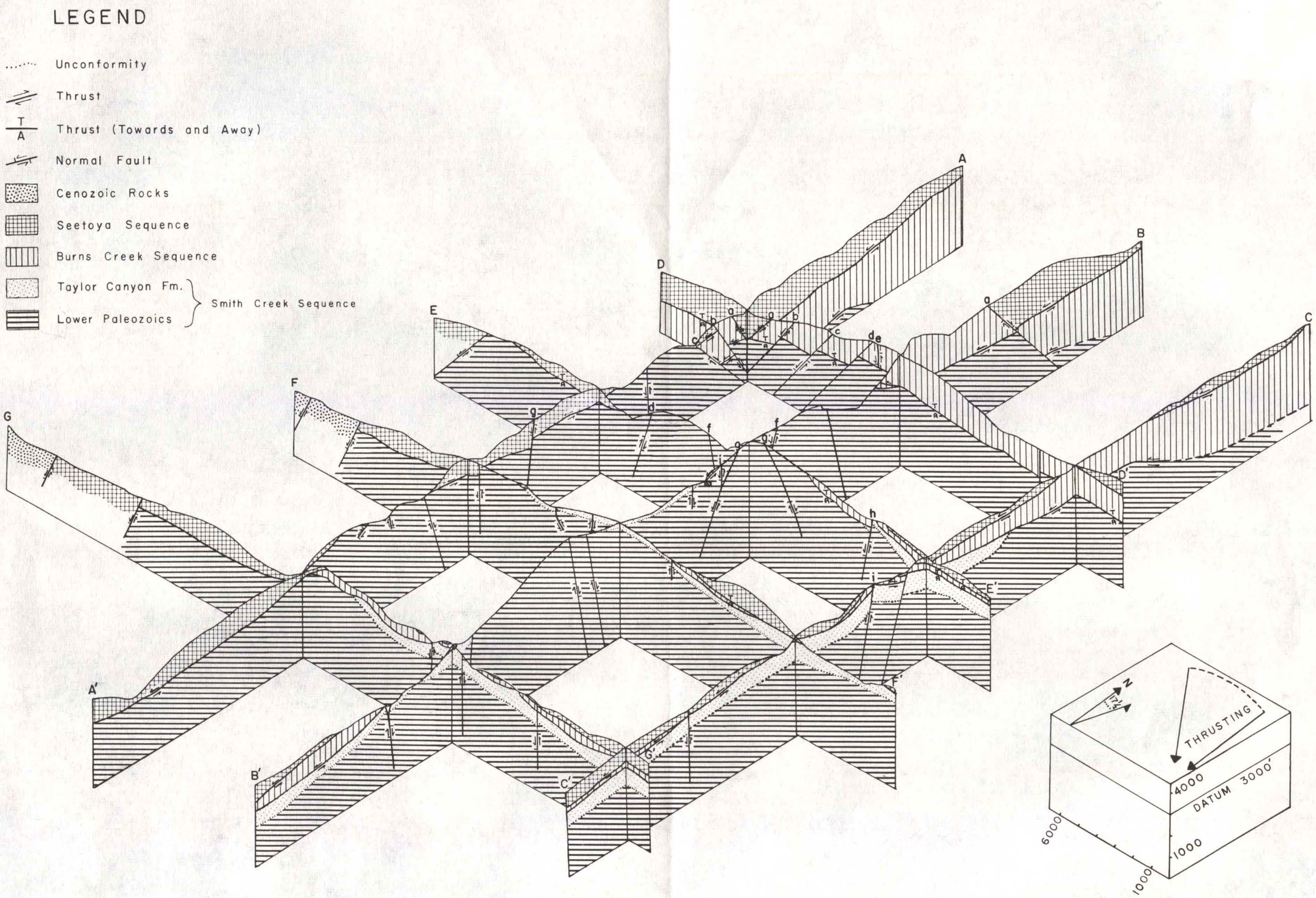
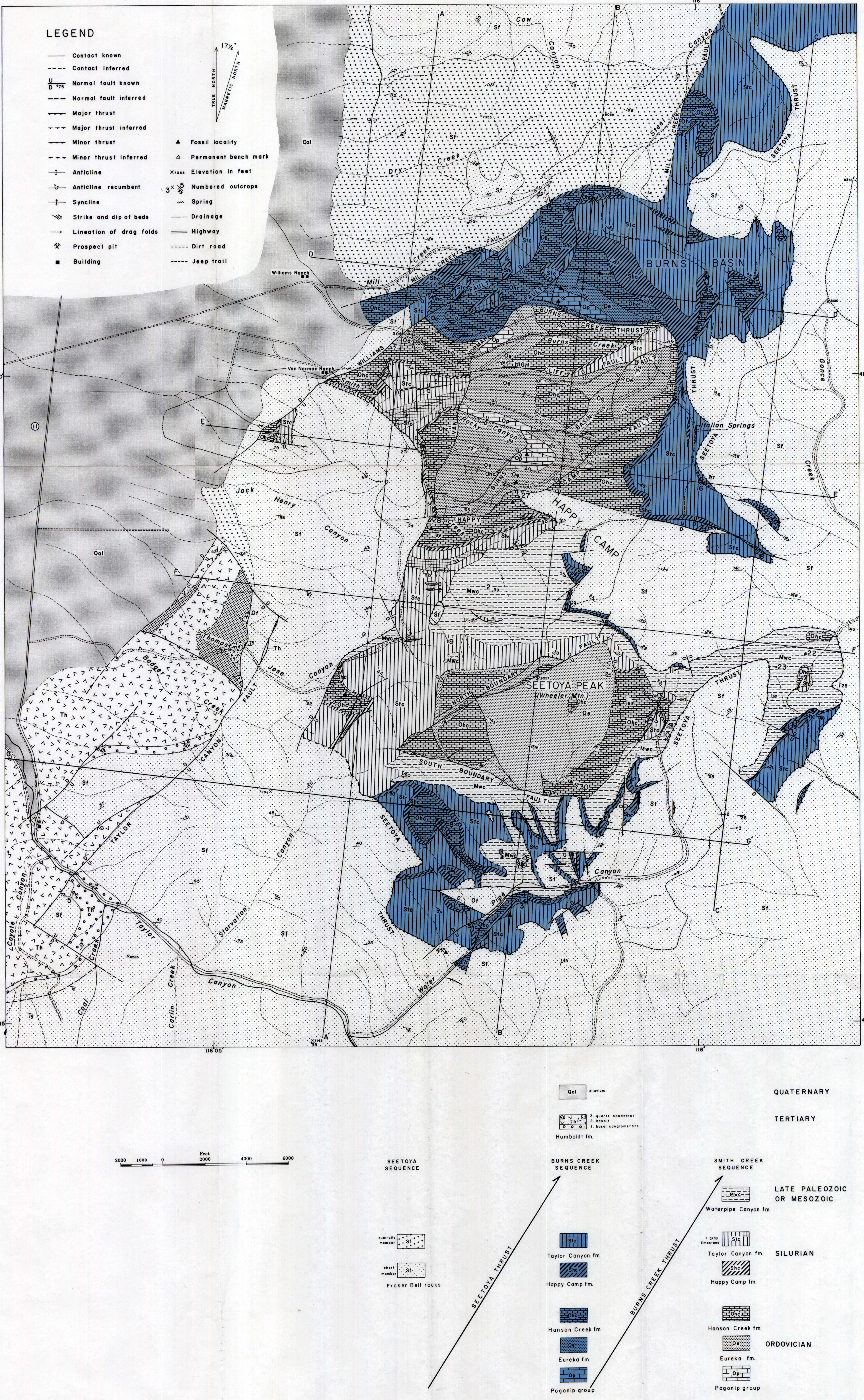


TRACE OF SECTIONS SHOWN ON PLATE I

FENCE DIAGRAM, SEETOYA MOUNTAINS, INDEPENDENCE RANGE, ELKO COUNTY, NEVADA

Important high-angle faults have been lettered alphabetically with lower-case letters, the letters being placed above the intersections with the surface. Corresponding letters on different sections indicate that the fault extends between the two points. Fault *h* in east-west section E-E′ is a normal fault dipping west.

KERR, PLATE 4
Geological Society of America Bulletin, volume 73



GEOLOGIC MAP, SEETOYA MOUNTAINS, INDEPENDENCE RANGE, ELKO COUNTY, NEVADA