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GEOLOGY OF THE ANTLER PEAK QUADRANGLE, NEVADA

by

Ralph J. Roberts, 1911-

Manuscript report in the Open Files of the

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Geology of the Antler Peak quadrangle, Nevada

By Ralph J. Roberts

ABSTRACT

The Antler Peak quadrangle is bounded by the meridians 117° and 117°15' and the parallels 40°30' and 40°45' in north-central Nevada. It is in the Basin and Range province and includes Battle Mountain, a north-trending range 18 miles long and 14 miles wide. The range is bounded on the east by the Reese River Valley, on the northeast by the Humboldt Valley, on the west by the Buffalo Valley, and on the south by a low divide separating the Buffalo Valley from the Reese River Valley. Altitudes in the quadrangle range from 4,475 to 8,550 feet; the local relief is as much as 3,500 feet, but is generally less than 2,000 feet.

The rocks of the area are principally sedimentary strata of Mississippian (?) to Permian age. These are cut by intrusive stocks and dikes of Mesozoic age. Tertiary volcanics and pyroclastic rocks overlie the older rocks, and Quaternary sediments partly fill the larger valleys and flank the range.

The upper Paleozoic sedimentary rocks occur in two separate facies which are separated by a major thrust fault--the Golconda thrust. The rocks in the lower plate of the thrust comprise units from Mississippian (?) to Permian age. Those of the upper plate are Pennsylvanian (?) and Permian (?) age. The two facies differ markedly in lithology. They were deposited in widely separated basins under different geologic environments.

The lower plate sequence includes six formations: three of these, the Scott Canyon, Valmy, and Harmony formations are thick units of Mississippian (?) age. The Scott Canyon formation consists of chert, argillite, greenstone, and quartzite; the Valmy consists of vitreous quartzite, chert, and argillite; the Harmony is sandstone, arkose, and shale. These formations have been complexly folded, and a major thrust fault, the Dewitt thrust, separates the Scott Canyon and Valmy formations from the overriding Harmony formation.

The relation of the Harmony formation to the other two is not definitely known, but is thought to be younger. The Scott Canyon and Valmy formations are also in thrust contact in this area, but in the Winnemucca quadrangle, the Valmy formation conformably overlies the Scott Canyon formation. The other three formations include the Battle formation and Antler Peak limestone of Pennsylvanian age, and the Edna Mountain formation of Permian age. The Battle formation (of Des Moines age) consists of about 700 feet of conglomerate, calcareous shale, and limestone; it rests unconformably upon the older rocks. The unconformity represents a major orogeny--the Antler orogeny. The Antler Peak limestone (upper Pennsylvanian), which overlies the Battle formation with apparent conformity, is composed mainly of limestone, pebbly limestone, and shaly limestone beds aggregating about 625 feet in thickness at the type locality. The Edna Mountain formation of Phosphoria (Permian) age comprising chert conglomerate, shale, and shaly limestone rests with erosional unconformity upon the Antler Peak limestone.

The upper plate sequence is made up of two formations: the Pumpernickel formation, consisting of about 5,000 feet of interbedded chert, shale, and greenstone is of Pennsylvanian (?) age; it is overlain conformably by the Havallah formation of Permian (?) age comprising interbedded chert, argillite, limestone, and fine-grained quartzite aggregating more than 3,000 feet in this area. The lower beds contain fusulinids of Wolfcamp and Leonard (?) age.

Intrusive igneous rocks including stocks of granodiorite and quartz monzonite crop out in Trenton Canyon, Copper Canyon, Copper Basin, and Elder Creek. Porphyry dikes related to the stocks are abundant west and south of Copper Basin and locally elsewhere in the area. In addition, there are related dikes of gabbro and diorite. Contact metamorphism of the intruded rocks has resulted in recrystallization of argillite, chert, sandstone, and conglomerate, and development of lime silicates in the carbonate rocks.

The rocks in the area have been subjected to four major orogenic movements, two during the Paleozoic, one during the Mesozoic, and a less intensive one during later Tertiary and Quaternary time. The earliest orogeny, here named the Antler orogeny, is confined to the lower plate sequence of the Golconda thrust, and took place in the Mississippian(?) and early Pennsylvanian. The Dewitt thrust fault and complex folding of the Mississippian (?) rocks belongs to this orogeny. The next orogeny, the Permian orogeny, was largely confined to the upper plate sequence of the Golconda thrust, but it also affected the lower plate sequence. The Mesozoic orogeny, which began in the Jurassic and probably continued into the Cretaceous, was characterized by thrust faulting and local folding; the Golconda thrust fault belongs to this orogeny. The igneous rocks were intruded later than the thrusting associated with this orogeny. Northward-trending normal faults followed the intrusions and were the loci for ore deposits in the area. Faulting probably continued into the late Mesozoic and Tertiary when Battle Mountain was blocked out on normal faults.

During the Tertiary, possibly in the Miocene, flows of rhyolite and associated pyroclastics probably covered much of the quadrangle. Subsequent erosion has removed much of this cover, leaving only remnants of these rocks in the range and on the flanks. Presumably near the end of Pliocene or possibly in early Pleistocene time, basalt flows were poured out on the southern and northwestern flanks of the range.

Following this volcanism, uplift of Battle Mountain continued, and it was sculptured into a rugged range. The four major geomorphic stages in the development of the range are: (1) mature upland stage, (2) canyon cutting, and fan building stage, (3) fan dissection stage, and (4) lake stage.

INTRODUCTION

The Antler Peak quadrangle is one of the 15 minute quadrangles of the Sonoma Range degree quadrangle. Mapping of the Sonoma Range quadrangle was begun in 1939 by H. G. Ferguson, S. W. Muller, and Ralph J. Roberts. The work was under the general direction of Mr. Ferguson. Mr. Ferguson and Mr. Muller mapped most of the areas underlain by Paleozoic and Mesozoic rocks. The Antler Peak quadrangle contained the principal mineral deposits in the area, so it was mapped on a larger scale, chiefly by Roberts. The area proved to be highly important in interpretation of the regional geology, for some of the stratigraphic and tectonic features are better shown in Battle Mountain than in the other ranges of the Sonoma Range quadrangle.

Location and accessibility

The Antler Peak quadrangle is in north-central Nevada in the northern part of Lander County and in the southeastern part of Humboldt County. (See fig. 1 and pls. 1 and 2). The quadrangle is bounded by longitudes 117°00'-117°15' and latitudes 40°30'-40°45'.

U. S. Highway 40 and the Southern Pacific Railway pass through the northeastern corner of the quadrangle, and Battle Mountain, the nearest town is 4 miles east of the quadrangle. The Western Pacific Railway is 4 miles north of Battle Mountain.

A graveled road extends from the town of Battle Mountain south-southwest along the east side of the quadrangle to Copper Canyon and nearby mining settlements. Connecting dirt roads afford access to the canyons on the east side of Battle Mountain. A graveled road extends from Valmy on

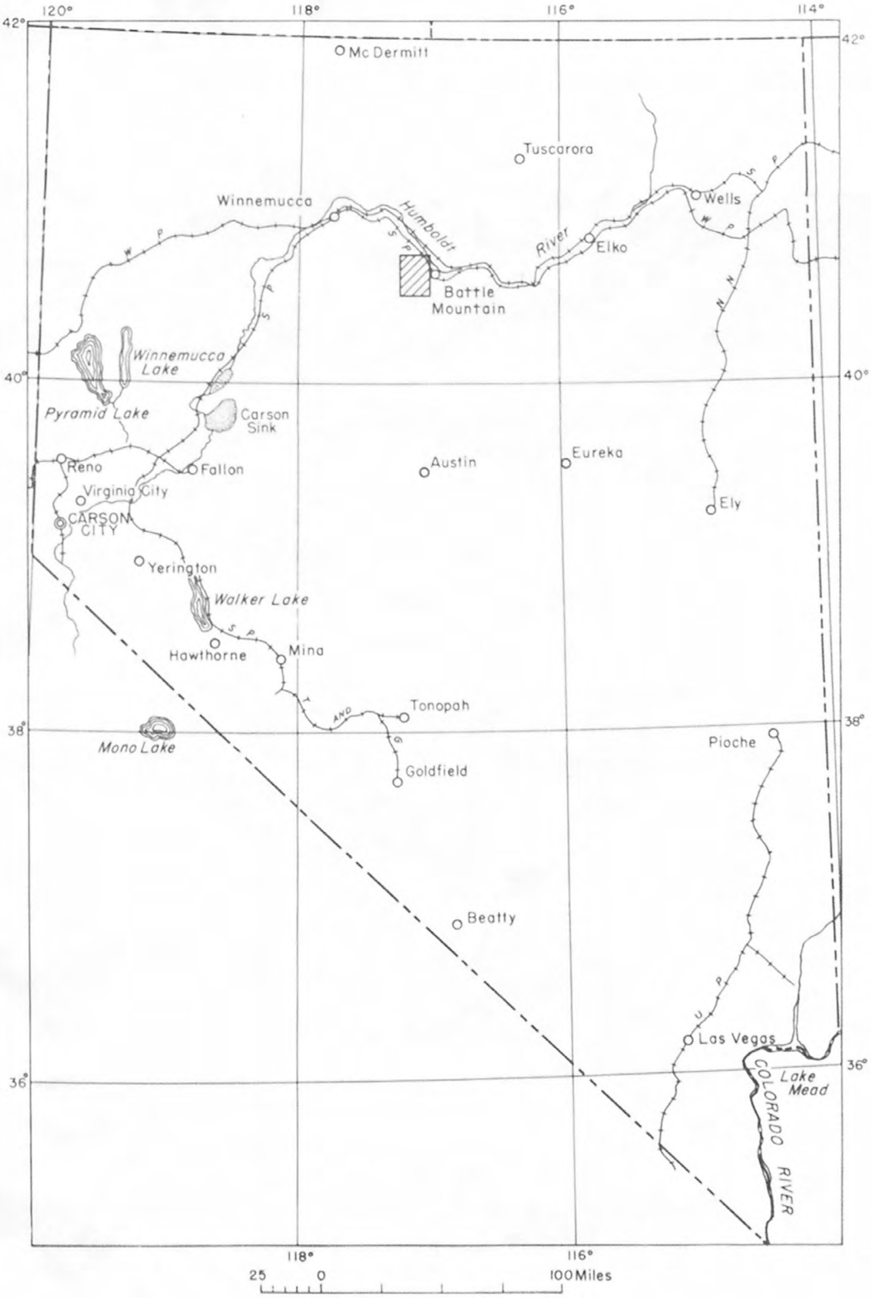


Figure 1. — Index map of Nevada showing location of the Antler Peak Quadrangle

U. S. Highway 40 south along the west side of the range into Buffalo Valley, and connecting dirt roads follow some of the major canyons. No roads, however, cross the range and most of the canyon roads end at altitudes of 6,500 feet or lower, leaving a considerable area in the center of the range accessible only on foot.

Previous work

The first published account of Battle Mountain is in the report of the Geological Exploration of the Fortieth Parallel by Clarence King and his associates. Battle Mountain was mapped during this geologic reconnaissance between 1867 and 1873 and shown as an area of Carboniferous rocks with Tertiary volcanics in a few places (Hague and Emmons, 1877), (King, 1899). In 1912 J. M. Hill (1915, p. 64 and Plate X) visited Battle Mountain and described the mines, but did not do any additional geologic mapping. Hill summarized the stratigraphy briefly, and made observations on the rocks exposed in and near the mines that he visited. In 1916 G. A. Waring (1917, pp. 95-129, Plate VIII) investigated the ground water resources of the Reese River valley, and showed part of Battle Mountain on his reconnaissance geologic map. In 1930 Schrader (1933) revisited the district to bring the mining data up to date. He did no additional geologic mapping, and confined his geologic discussion to previously published accounts. References to the mines of the Battle Mountain district have been made in technical journals since then, but there has been no additional geologic work done in the area up to the time of the present study.

Field work and acknowledgments

Mapping in the Antler Peak quadrangle was begun in June 1941 and continued until August 1941. Field work was carried on throughout September and October 1942. Then, delayed by World War II, field work was resumed in July 1946 and continued until November; then begun again in July 1947 and lasted until March 1948.

Through all the field work H. G. Ferguson spent considerable time in the area with the writer. Mr. Ferguson's broad experience in Nevada geology, as well as his familiarity with the Paleozoic section in other parts of the Sonoma Range quadrangle were of inestimable value in working out the geology of Battle Mountain. Mr. Ferguson has also critically read this report, and has suggested revisions which have greatly strengthened the report. S. W. Muller has also read the report and has offered many helpful suggestions and criticisms.

For varying periods of time Arthur E. Granger, W. Manning Cox, Claude C. Albritton, Edgar F. Scholz, Wilfred J. Carr, John L. Rich, J. Frederick Maier, Paul D. Proctor, and Calvin C. Covell assisted in the field work. These men all cooperated enthusiastically and greatly aided the field work.

James Steele Williams and Lloyd G. Henbest of the Geological Survey visited the writer in the field, and in addition to making the determinations of the fossils collected, gave him the benefit of their knowledge of sections of Paleozoic rocks elsewhere in the western states.

Professor Chester R. Longwell of Yale University visited the writer in the field in 1947. Stimulating discussions with Professor Longwell suggested new lines of attack on several perplexing problems, and his suggestions have contributed greatly to the report. The writer is also indebted to Professors

Adolph Knopf, Carl O. Dunbar, Richard F. Flint, and John Rodgers, all of the Department of Geology of Yale University. Their many suggestions and helpful criticisms have greatly improved the report.

The writer also owes a debt of gratitude to members of the Geological Survey who have worked in nearby areas, and have exchanged visits and discussed problems of mutual interest. Among these are Roger S. Morrison, Donald E. White, and S. Warren Hobbs.

It is a pleasure to acknowledge the cooperation and hospitality of Robert H. Raring, General Manager of the Copper Canyon Mining Company. Permission was given to map the underground workings on property of the company, and all mining and geologic data in the files of the company were made available to the Geological Survey. The helpful cooperation of all the members of Mr. Raring's staff, especially Ralph Hayden, L. W. Snow, and William D. Kerns is also acknowledged.

Sincere thanks are extended to members of the Geological Survey who have aided the writer during the preparation of the report. The following have been especially helpful: E. N. Goddard, L. W. Pusey, C. S. Ross, K. E. Lohman, R.E. Van Alstine, J. B. Hanley, Jane Titcomb, M. F. Willoughby, Mrs. E. L. Harper, Mrs. Elizabeth Kuhleman, Mrs. Mary Black, N. M. Shupe, C. W. Bennett, F. S. Reed, J. L. Mergner, Doswell Olson.

Geography

Surface features

The Antler Peak quadrangle covers Battle Mountain, a range 18 miles long and 14 miles wide in its central part. The range trends northward, and except for the low hills joining Battle Mountain and the Buffalo Range on the northwest, is isolated from the surrounding ranges by waste-filled valleys. Viewed from the southeast (pl. 4) Battle Mountain is not impressive, for it rises gradually from Buffalo Valley and the Reese River Valley; but from the west, north, and northeast the mountain is imposing standing out above Humboldt Valley. The highest peak is North Peak, rising to 8,550 feet above sea level. Antler Peak, which gives the quadrangle its name, is the next highest point rising to 8,236 feet. The lowest point is the valley of the Humboldt River at an altitude of 4,475 feet in the northeastern part of the quadrangle. The maximum relief is 4,075 feet, but the local relief is less; near North Peak it is 3,500 feet, but elsewhere it is generally less than 2,000 feet. The west and north slopes of the range are extremely rugged, but the south and east sides are less rugged and slope smoothly down to the valleys.

On the north, Battle Mountain is bordered by the Humboldt valley through which the Humboldt River flows. (See plate 9.) At the town of Battle Mountain the Humboldt valley is 8 miles wide. The present river is obviously underfit, and could not have carved its valley. The valley it follows is probably structural in origin, formed by block faulting which juggled horsts and grabens and deflected the river in a zigzag course across northern Nevada.

The Humboldt River flows in a meandering course in a broad flood plain a mile to two miles wide. Meander scrolls, cutoffs, and oxbow lakes are arranged in intricate patterns along the flood plain. The main channel is sluggish and has a gradient of about 2 feet per mile (Robinson, 1948); the flood plain has a gradient of about $4\frac{1}{2}$ feet per mile, showing that the meanders cover more than two times the length of the valley along its axis. The river is at grade and carries a heavy load of silt in the flood seasons. Because of the relatively small supply of water, floods are rarely a problem in the Humboldt valley. Low areas are commonly inundated in the spring, but destructive floods are unknown.

The Reese River valley on the east separates Battle Mountain from the Shoshone Range. (See plates 7 and 8). This valley is 6 to 8 miles wide; the fans on the southeastern side of Battle Mountain extend out from the range nearly to the river whose channel cuts across the southeastern corner of the quadrangle. The river flows northward in a broad arc, convex eastward, and joins the Humboldt river just north of the northwestern corner of the quadrangle.

South of Battle Mountain the Reese River Valley opens westward into Buffalo Valley, a closed basin between Battle Mountain on the northeast, the Fish Creek Range on the east, and the Tobin Range on the west. (See pl. 3.) The Buffalo Valley extends northward to a divide separating it from the Humboldt Valley near the northwestern corner of the quadrangle.

Drainage

Several small streams, fed by rainfall, snow, and springs drain the range and discharge radially into the surrounding valleys. The more important of these streams are Willow Creek, Duck Creek in Galena Canyon, Little Cottonwood Creek, Elder Creek, Trout Creek, Cottonwood Creek, Trenton Creek, Mill Creek, and Rocky Creek. (See plate 1.) Within the range Willow Creek, Cottonwood Creek, Duck Creek, and Trenton Creek are perennial streams, but after emerging from the range they become intermittent. All the others are intermittent within the range as well as outside. Even during the months of greatest precipitation the streams do not normally join the Humboldt or Reese Rivers, but sink into the lower parts of the alluvial fans. It is likely, however, that in the past, during periods of exceptionally heavy precipitation such as cloudbursts, the streams reached the Humboldt and Reese Rivers, for the fans and beaches have been incised by streams flowing from the major canyons.

The radial pattern of the streams is of course partly dependent on the form of the range. The major streams are spaced at more or less equal intervals around the range but the texture of the topography is rather fine as in most semiarid to arid regions. The principal drainage divide, separating streams flowing eastward from those flowing westward, is near the center of the range near North Peak. From here the divide curves eastward to a point near Copper Basin then southwestward to Antler Peak, and then southward to the border of the range. The ridge pattern in both the western and eastern parts of the range is complex in detail, but on the whole it is a radial pattern.

The major streams have interesting courses. Willow Creek, a stream flowing parallel to the structure in the lower part of its valley, extends much farther into the range than most of the others. In addition, Willow Creek has a broad valley in its lower reaches, but a narrow canyon in its upper reaches and tributaries. Part of the explanation for this may be that Willow Creek has captured tributaries of the south fork of Cottonwood Creek which formerly headed just southwest of Antler Peak. (See plate 1.) One tributary flowed northwestward past the 7196 ridge; a small remnant of the coarse gravels deposited there during the early uplift of the range is still preserved on the top of the ridge. Where the tributary now joins Willow Creek there is a gorge with precipitous falls cut into the Antler Peak limestone. In secs. 29-30, T. 32 N., R. 43 E. capture of another tributary of Cottonwood Creek is imminent.

The causes of the capture are not entirely clear, but two factors were probably important. One of these is that Willow Creek is a subsequent stream, and worked headward along a belt of weak rock--the argillitic facies of the Pumpernickel formation. The stream in Cottonwood Canyon, on the other hand, flows across resistant quartzite beds of the Valmy formation and consequently has had difficulty in cutting down. The other factor is that Cottonwood Canyon has gradually lost its headwater basin as streams from the eastern and southeastern side of the range have pushed the divide westward.

Another possible change of direction of drainage is indicated in the upper reaches of Duck Creek above Galena. Here Duck Creek flows southward parallel to the course of Copper Canyon and may well be a beheaded former extension of Copper Canyon. The reason for this capture is probably that Duck Creek had a base level advantage over any stream formerly flowing in Copper Canyon and thus was able to effect the capture. Now that the volume of water in Duck Creek is much greater than that in Copper Canyon the permanency of the capture is assured.

Climate and vegetation

The climate in this part of Nevada is arid and the valleys normally receive about 6 inches of rainfall annually, but the recorded range at Battle Mountain (altitude 4,513 feet) is from 3 inches to 14.0 inches (Waring, 1917, pp. 102-104). Most of the precipitation falls during the winter and spring months, largely as snow in the mountains and as rain and light snows in the valleys. During some years heavy rainfal has been recorded in June and September but during July and August only local showers fall. Rainfall at the higher altitudes is greater and averages about 12 inches annually at Austin

(7,000 feet) 80 miles to the south of Battle Mountain (Blair, 1941, p. 979).

The maximum temperature recorded at Battle Mountain is 112°F and minimum -40°F. The January average is 28.4°F and July average is 74.7°F.

The vegetation in the range at altitudes above 5,000 feet is characterized by scattered juniper stands (*Juniperus scopulorum*) which extend as high as 7,700 feet and are best developed on the west and southwest part of the range. The junipers are accompanied by the characteristic sagebrush association (*Artemisia tridentata* and *Artemisia nova*), which becomes more luxuriant and thicker on the lower slopes and fans. On the valley bottoms the sagebrush gives way to shadscale association (*Atriplex confertifolia*) which grows best on clayey, alkaline soils.

SEDIMENTARY ROCKS

General statement

The rocks exposed in the Antler Peak quadrangle include a wide variety of sedimentary rocks, intrusive igneous rocks, lavas, and pyroclastics. They range in age from Mississippian (?) to Recent, and have been divided into 5 principal groups: (1) sedimentaries and volcanics of Mississippian (?) age, (2) sedimentaries of Pennsylvanian and Permian age, (3) intrusive igneous rocks of Mesozoic age, (4) volcanic rocks and pyroclastics of Tertiary age, (5) valley fill, gravels, and lake deposits of Pleistocene and Recent age.

The Antler Peak quadrangle contains a thick section of upper Paleozoic rocks, and is the type area of four of the seven formations which underlie the greater part of the quadrangle. The most significant geologic feature in the quadrangle is that the sedimentary rocks of Carboniferous and Permian age occur in two separate facies which are separated by a major thrust fault--the Golconda thrust of Mesozoic age. The rocks in the lower plate of this thrust comprise units from Mississippian (?) to Permian age, those of the upper plate are Pennsylvanian (?) and Permian (?). The two facies differ markedly in lithologic character, and although approximately equivalent in age, they were deposited in widely separated basins under entirely different geologic environments.

Lower plate sequence

The sequence in the lower plate of the Golconda thrust comprises six formations; the first three, the Scott Canyon, Valmy, and Harmony formations, are thought to be of Mississippian age. These rocks have been highly folded and cut by both thrust and normal faults. A major thrust fault, the DeWitt thrust, separates the Scott Canyon and Valmy formations from the overriding Harmony formation. Two of the younger formations, the Battle formation and the Antler Peak limestone, are of Pennsylvanian age. The third, the Edna Mountain formation is Permian. These rocks rest unconformably upon the folded and faulted older rocks (Mississippian) (?), thus limiting the orogeny to the time between the late Mississippian (?) and early Pennsylvanian. This orogeny will henceforth be referred to as the Antler orogeny to distinguish it from a later orogeny which took place in Permian time.

Scott Canyon formation

Areal distribution and thickness.--The Scott Canyon formation, is here defined and named for Scott Canyon, a tributary of Galena Canyon in secs. 11 and 14, T. 31 N., R. 44 E. The formation is well exposed on the southeastern slopes of Battle Mountain, especially in Galena, Little Cottonwood, and Scott Canyons. Beds assigned to the Scott Canyon formation are also exposed in the headwaters of Trout Creek and Cottonwood Creek, and on the east slopes of North Peak.

The base of the formation is not exposed in the Antler Peak quadrangle. In the Sonoma Range, Sonoma Canyon (Winnemucca quadrangle, Ferguson, Muller, and Roberts, 1949) rocks assigned to the Scott Canyon formation are in thrust contact with rocks of Cambrian and Ordovician age, so its normal relation to underlying rocks is unknown. In the southeastern part of the Antler Peak quadrangle the Scott Canyon formation is overridden by the rocks of Harmony formation on the Dewitt thrust fault. (See plate 2, section C-C'). In the headwaters of Cottonwood Creek the Scott Canyon formation is overlain unconformably by conglomerate of the Battle formation of lower Pennsylvanian age.

Lithology.--The Scott Canyon formation is mapped as a unit, but for purposes of description it is divided into two members. The lower of these consists of interbedded chert, argillite, and some quartzite; the upper member includes greenstone, chert, argillite, and some limestone. The greenstones and argillites commonly form smooth slopes with clayey soils and are exposed only in stream channels. The cherts crop out prominently forming strike ridges capped by rough, craggy outcrops; the slopes underlain by chert are mantled by thin stony soils.

The lower member of the formation is exposed in the area southeast of North Peak and in the headwaters of Trout and Cottonwood Creeks. This part consists of interbedded chert and argillite. The cherts are mostly dark in shades of gray, brown, and black, and for the most part thin bedded. The argillite is dark brown or black, and appears to contain considerable organic material. The relative amounts of argillite and chert vary from place to place, but the argillite appears to predominate near North Peak and the chert is predominant elsewhere.

The kind of rock present below the Dewitt thrust in the intervening area between the headwaters of Cottonwood Creek and Little Cottonwood Creek is not known, but is presumed to be the lower member of the formation.

The upper member of the Scott Canyon formation is exposed in the southeastern part of the quadrangle in Galena and Cottonwood canyons below the Dewitt thrust. No detailed section was measured, but the member consists of greenstones which occur as massive flows, pillow lavas, breccias, and pyroclastics of andesitic or basaltic composition intercalated with chert and argillite and minor amounts of limestone.

Thin sections of the greenstones generally show that they have been highly altered; the mafic minerals to serpentine and chlorite, and the feldspar to clay minerals. (See pl. 20.) In some thin sections, however, the feldspar and dark minerals seem to be relatively fresh and are set in a groundmass of glass. The feldspar is plagioclase whose composition is about An_{40} and the rock is therefore considered andesitic. Augite is the most abundant dark mineral. It is present in phenocrysts and grains, partly altered to serpentine, epidote and calcite.

Cherts intercalated with the greenstone are mostly thin bedded, but in places massive layers 12 to 18 inches in thickness are interbedded with the thin-bedded layers. (See plates 16, 18A.) The chert is gray, black, dark brown and green, predominantly in dark shades, but light shades are locally interbedded. The layers are characteristically lenticular, pinching and swelling along the strike, and are separated by partings or layers of argillite. In places the cherts are finely laminated, and as many as 20 layers to the inch can be counted. In thin section they are seen to be composed chiefly of cryptocrystalline silica, probably chalcedony, with small patches and veinlets of fine-grained quartz. In places the chert is opaline and is isotropic. Some of the sections studied show small quartz grains, commonly angular, scattered throughout the groundmass. The grains range in size from 0.01 to 0.04 millimeters and average about 0.02 millimeters in diameter. Calcite is also a common constituent of the cherts; generally it is present in subhedral to euhedral crystals scattered throughout the rock, but in places it forms veinlets of anhedral crystals.

Pyroclastic rocks intercalated with the lavas, cherts, and argillites were not studied in detail, but such rocks make up much of the upper part of the Scott Canyon formation. In specimens examined, the fragmental texture is clearly shown in hand specimens as well as under the microscope. In the coarse facies, fragments of aphanitic volcanic rocks are abundant, but commonly these are highly altered and the original minerals are not determinable. Generally only relics of trachytic, pilotaxitic, or similar textures are indicated by arrangement of the minerals. In addition to the volcanic fragments, plagioclase grains and quartz occur in the groundmass. The coarse facies grade into a finer facies whose composition is less clear, but which probably is chiefly derived from volcanic and pyroclastic sources.

A minor constituent of the upper part of the formation is the limestone associated with pillow lavas at the range front near the mouth of Galena Canyon and in Little Cottonwood Canyon. The limestone is light to medium gray and is highly recrystallized and broken by minute fractures. It is exposed just below the Dewitt thrust fault, and seemingly forms lenses carried along the thrust plane.

Age.--At two places meager fossil collections were made in the limestone. The first is a locality near the center of sec. 2, T. 31 N., R. 43 E. north of the 7,005 peak. Crinoid fragments found in the limestone proved to be indeterminate.

At the other locality near the center of sec. 1, T. 31 N., R. 43 E. lenses of limestone associated with pillow lavas contain fossil sponges. These were examined by Helen Duncan of the Geological Survey who writes as follows: "

"The slabs from your locality 305 in the (Scott Canyon) formation are full of sponges... and algae. The algae are of a type I have not seen before. They look something like Mitcheldeania. Dr. Brown said he did not think there was any doubt that they were algae, but he is uncertain as to their generic identity.

The most abundant and conspicuous sponge can be identified as a Heliospongia. Inasmuch as the specimens from the (Scott Canyon) formation are considerably less robust than the species hitherto described, I believe they should be considered a new species. It is difficult to be sure about this, as I have only sections for study and practically all sponge genera are based on weathered or etched specimens that show gross form and external features, which cannot be determined when the specimens are embedded in matrix. I think the slabs contain at least two other genera of sponges, but the specimens are too fragmentary and poorly preserved for me to identify.

Owing to their restricted occurrence as fossils, sponges are at present of little value for stratigraphic correlation or age determination. I showed your specimens to Dr. Kirk, who said he had never seen anything like them in the Ordovician, Silurian, or Devonian rocks of Nevada. I have looked up the literature on Mississippian sponges and find that most of the described species are hexactinellids which were collected from the east-central interior. We have few records of sponges in the Carboniferous rocks of western North America. These occurrences are noted simply as "sponges", genera not being identified nor species described. Three species of Heliospongia have been described, two from the upper Pennsylvania of Kansas and Texas, and one from the Permian of Texas. There is no record of the genus in older rocks, but I see no reason that its range should not be extended into the Mississippian at least."

The Scott Canyon formation is in thrust contact with the Valmy formation and both are overlain unconformably by the Battle formation of lower Pennsylvanian age. The sponges found in the Scott Canyon formation are not definitely of Mississippian age, but both Dr. Kirk and Helen Duncan consider them to be clearly younger than Devonian. The Scott Canyon formation is therefore post-Devonian and pre-lower Pennsylvanian; as the erosion interval prior to the deposition of the lower Pennsylvanian was obviously a long period of time, the Scott Canyon formation is considered as Mississippian (?) age.

Valmy formation

Occurrence.--The Valmy formation here named and defined is exposed on North Peak and the adjacent area in the northwestern part of the quadrangle, forming an elliptically shaped outcrop about 7 miles long, beginning a mile south of Cottonwood Creek and widening at the north to 4 miles at the range front. The best exposures are on the northwest side of North Peak, designated the type area, and in the valleys of North Fork and Trout Creek. The name of the formation is derived from the station of Valmy, on the Southern Pacific Railway, and U. S. Highway No. 40, which is about 2 miles north of the border of the quadrangle. (See Plate 3.)

Sequence and lithologic character.--Because of the complex folding and and faulting which the rocks in North Peak and adjacent areas have undergone, little is known of the stratigraphic succesion within the formation. The upper beds appear to be predominantly chert, shale, and some quartzite, and the lower beds are mainly quartzite, shale, and chert. A greenstone flow intercalated with the lower beds is exposed on the ridge between the North Fork and Trout Creek. No measurement was made of the thickness of the formation. It is estimated, however, that it aggregates more than 3,000 feet and may be as much as 5,000 feet.

The lower beds which underlie North Peak and the adjacent area on the south are predominantly vitreous quartzite. It is medium to coarse grained, generally white, light gray, or medium gray but in places almost black. In thin sections the quartz grains are seen to be seriate and unsized; (see plate 18 B) they range from .15 to .60 mm in diameter and the larger sizes appear to predominate. They are commonly subrounded to rounded and their borders are typically sutured. Adjacent grains have been so subjected to pressure that commonly one indents the other. Because of the crystallization of the groundmass little cement remains. Silica was probably the dominant original cementing material, but was reprecipitated on the clastic grains during metamorphism.

Age.-- The Valmy formation is in thrust contact with the Scott Canyon formation, and both are overlain unconformably by the Battle formation of lower Pennsylvanian age. In the Winnemucca quadrangle about 25 miles to the northwest, rocks assigned to the Valmy formation rest with apparent conformity upon intercalated cherts, greenstone, and argillite correlated with the Scott Canyon formation. (Ferguson, Muller, and Roberts). The Valmy formation therefore would appear to be younger than the Scott Canyon formation, and will be considered Mississippian (?) in age.

Harmony formation

Occurrence.--The Harmony formation underlies most of the northeastern part of Battle Mountain and is also present in the southeastern part where it has been locally downfaulted. It rests on rocks of the Scott Canyon formation, but the contact is discordant everywhere and is a thrust fault of great magnitude. The type locality of the Harmony formation is Harmony Canyon in the Sonoma Range (Ferguson, Muller, and Roberts).

The rocks of the Harmony formation are generally not resistant, and commonly form smooth slopes, broken locally by outcrops of sandstone and grit. (See plate 13 B). The best exposures are near the northern crest of the range at the head of Snow Gulch, and on the eastern side of the range at the head of Little Cottonwood Canyon.

Because the Harmony formation is found only in the upper plate of the Dewitt thrust fault, its stratigraphic relations are not known. Moreover, the beds are highly folded and overturned in places, and it is impossible in most places to determine whether they are right side up or not. The major structure in the Harmony formation appears to be a syncline overturned to the east whose axis trends northward just east of the Dewitt mine (sec. 23, T. 32 N., R. 43 E.) into the head of Elder Canyon. In the Copper Basin area the beds dip eastward, and probably belong to the upper part of the formation. No section was measured, but the formation is estimated to be at least 3,000 feet thick.

Lithologic character.--The Harmony formation is composed of approximately equal proportions of interbedded shale and sandstone which are commonly greenish brown. In places the sandstone is dark reddish brown, and the shale is dark red, but greenish shades are predominant. Weathered sandstone outcrops are greenish brown to light brown.

The sandstones are commonly coarse grained, and some of them can be called grits for they are both coarse and have typically angular fragments (Twenhofel, 1932, p. 229). The coarse sandstones grade locally into granule conglomerate, and into medium and fine sandstones.

One of the remarkable features of the Harmony formation is that much of it is arkosic. (See plates 21 and 22). Some beds contain 20 percent or more feldspar, chiefly orthoclase, microcline, and microperthite; plagioclase, generally albite or oligoclase, is also present. The feldspar grains are for the most part entirely fresh and generally angular. In coarse arkosic sandstones the feldspars are less well rounded than the quartz, but this is not true everywhere. The quartz grains generally show strain shadows, and some of them are made up of still finer grains with sutured borders.

The quartz fragments in the Harmony formation are of three types; clear quartz, smoky quartz, and milky quartz. The clear quartz grains are either parts of a single quartz crystal or are rounded fragments of quartzite. Some of the grains of quartzite are undeformed, but in others the texture is distinctly schistose as the grains have sutured borders and are elongated in parallel alinement. The smoky quartz owes its opacity to minute opaque inclusions. The inclusions are sparse in some grains, but in others are thickly set, and are locally arranged in lines. The milky quartz owes its appearance to vacuole inclusions and clay inclusions, but the exact nature of the inclusions is not clear.

The feldspars are accompanied by biotite and muscovite which range from large plates as much as a millimeter across to fine shreds. The micas were probably derived from the same source rock as the feldspar; they are clearly detrital and much frayed and broken during transport.

The Harmony formation was derived from a terrain underlain by granitic and possibly metamorphic rocks. No granitic rocks older than Jurassic are known in the Sonoma Range quadrangle or adjacent areas, but the source area evidently contained granitic rocks, of pre-Mississippian age. The source area is not now exposed, but is buried under younger sediments. No idea of the direction of the source area can be obtained, for the formation is rather similar in character throughout the parts of the Sonoma Range quadrangle where it is exposed.

Near granitic intrusives the Harmony formation is metamorphosed; the sandstones to quartzite, and the shales to hornfels. (See plates 23 and 24). The mineralogic changes that have taken place change the color markedly; the sandstones become lighter, first light brown or light gray, then white. The quartz grains are changed little in most of the specimens studied, but the feldspars are first altered to sericite, then recrystallized to secondary orthoclase, biotite, and muscovite. The rock is crystalloblastic in texture, and the final product resembles a quartzite. The shaly beds are darker in contact zones, and are generally dark-brown biotite hornfels. Adjacent to the intrusives the grain size is coarser, and there is generally some leaching because of hydrothermal activity.

Age.--The Harmony formation is overlain unconformably by the lower Pennsylvanian Battle formation and is therefore pre-Pennsylvanian in age. It is in thrust fault contact with the Scott Canyon and Valmy formations, and its stratigraphic relations to them are not known. On the whole the amount of deformation which the Harmony formation has undergone appears to be less than that of the Scott Canyon and Valmy formations. This difference may be due partly to the fact that the Harmony formation probably was deposited in a separate basin, but the principal reason could well be that the Harmony formation is younger and hence less deformed. It is recognized that this is not diagnostic, and the relative ages of the three formations are not known. On the explanation of plate 2 the Harmony formation has been placed above the other two, and will be tentatively considered of Mississippian (?) age.

Diabase.--Diabase sills and dikes intrude the rocks of the Harmony formation, and in places form prominent outcrops. The sills have aided in working out the structure of the formation for they appear to be most abundant at a definite horizon and persist throughout the quadrangle. The best exposures of the sills and dikes are along the south slope of Cow Canyon and along the ridge at the head of Little Cottonwood Canyon where they were intruded along the axis of an overturned syncline, but they are also present in other places. Most of the intrusions took place prior to the folding, for the sills follow the intricate minor folds of the Harmony formation, and are jointed like the more competent sandstone beds with which they are associated. The sills are from a few inches to as much as 8 feet thick and appear to be rather persistent along the strike; generally individual bodies cannot be traced for more than a few hundred feet because of poor exposures, but the zone of intrusion can be traced for miles by float and occasional outcrops.

Thin sills and dikes are commonly aphanitic, but thick sills generally have aphanitic border facies a few inches thick, and grade into rock of medium-grained diabasic texture in the center. The aphanitic border facies is typically intergranular in texture, but the central part may be either intergranular or ophitic. The plagioclase laths are as much as a millimeter long and on the whole are well twinned. The average composition of the plagioclase is about An_{55}. The augite that occurs in small interstitial grains and large crystals is partly altered to talc or serpentine and is locally replaced by secondary calcite which is present in most specimens. A little interstitial quartz is generally found, but it probably does not make up more than a fraction of 1 percent of the rock.

Occurrence.--The Battle formation which is here named and defined is in many ways the most interesting formation exposed in the quadrangle. In addition to being the host rock of the ore deposits in the Copper Canyon area, it is of special interest because it rests unconformably upon the older rocks of the lower plate sequence, thus marking an orogeny which may prove to be of regional significance. It is composed largely of conglomerate and sandstone with minor amounts of shale and limestone.

The Battle formation is exposed in three areas; a belt extending diagonally northwestward across the quadrangle; several small areas in Copper Basin; and a narrow outcrop near the head of Rocky Canyon.

The principal exposures are in a narrow belt less than a mile wide extending from the south-central part of the range northward to Wild Horse Basin, then northwestward to the headwaters of Trenton Canyon. From this point the Battle formation is only sporadically exposed northward to the Marigold mine. Throughout the entire distance the formation is complexly faulted, and in places it is cut out entirely by faults. The best exposures are southeast of Antler Peak on the west side of Cow Canyon, a tributary of Galena Canyon, where the lower two-thirds of the formation makes nearly vertical cliffs. (See plates 6, and 11A). The upper third of the formation crops out on the north and east slopes of Antler Peak. (See plate 5). These exposures aggregate about 700 feet in thickness and are designated as the type section.

In Copper Basin the Battle formation has been complexly faulted, and only small erosional remnants remain. The thickest part of the section appears to be on the ridge northwest of the Copper King mine (see plate 1) where the beds total about 150 feet thick, chiefly conglomerate. The conglomerate contains chert and quartzite pebbles and the matrix is silicified in the mineralized areas.

The narrow outcrop of the Battle formation near the head of Rocky Canyon is in a fault sliver. The exposures are poor although the formation can be traced about a thousand feet by float.

Lithology.--At the type section the Battle formation is composed chiefly of interbedded conglomerate and sandstone, together with some shale, calcareous shale, and limestone. These beds are highly resistant to weathering, and the formation is well exposed where it is present throughout most of the quadrangle. For purposes of description the formation will be divided into three parts.

The lower part (154 feet thick) is medium- to thick-bedded conglomerate, characteristically medium to deep red where unmetamorphosed. The rock fragments are poorly sorted; they range from boulder to granule size in a sandy to silty matrix containing iron oxide and locally calcite cement. The rock types found include sandstone, quartzite, chert, limestone, greenstone, and jasper. For the most part they can be classed as subangular, but locally, they are subrounded to well rounded. (See plates 11 B, 12 B, and 13 A).

Features such as current bedding and torrential bedding are found in the lower part of the formation, but are rarely well developed. They are commonly restricted to a single bed or group of beds, and indicate minor variations in conditions of deposition.

The middle part (244 feet thick) shows better sorting and more uniform bedding than the lower part, and fewer boulder beds. Cobble and pebble conglomerate beds and sandstone predominate; some shaly beds are present.

The upper part (300 feet thick) consists largely of pebble and granule conglomerate interbedded with sandstone, shale, calcareous shale, and limestone. The conglomerates and sandstone are generally lighter red than the lower and middle beds, and show still better sorting. The shale and calcareous shale are light red, yellow, brown, or buff. The limestones are gray to buff and commonly have a sugary texture; they grade into calcareous shales along the strike.

The lithology of the formation in Copper Basin is obscured by contact metamorphism and subsequent hydrothermal alteration, and as a result the conglomerate is silicified and leached light gray. It is composed of pebble and granule conglomerate with a few cobble beds, interlayered with sandstone. Commonly it is medium to thick bedded and generally well stratified. The fragments are subangular and subrounded for the most part, and are embedded in a sandy matrix. Part of the material is sandstone and argillite derived from the underlying Harmony formation, but most of the cobbles, pebbles, and granules were derived from the Scott Canyon and Valmy formations.

Detailed sections.--No single exposure shows a continuous section of the formation. Accordingly, a composite section was measured at the type locality.

Sections A and B, representing the upper part of the type section, are about the same thickness, and are probably equivalent stratigraphically.

Section C represents the lower part of the type section; it overlaps with sections A and B. The limestone bed 4 feet thick near the bottom of section B is probably equivalent to the limestone bed 6 feet thick at the top of section C. If the thickness of the lower part (475 feet) is added to the thickness measured in Section B of the lower limestone and higher beds (225 feet) a total thickness of 700 feet is obtained.

Composite section of the Battle formation

Section A, measured 500 feet southeast of Antler Peak. (See plate 7).

Antler Peak limestone.	Feet
Shale, siltstone, fine sandstone; red, thin bedded. Shale layers average 1/8 to 1/4 inch thick. Upper beds are red, yellow, and brown calcareous shale.	140
Conglomerate, light brick red. Pebbles chiefly chert, quartzite, and some limestone in coarse sandy matrix.	98
Sandstone, pebbly sandstone, shale, and limy shale. Sandstone, light to dark reddish brown grading into yellow sandstone at top, thin to medium bedded, containing limy nodules and layers. Shale and limy shale, gray to yellowish, thin bedded.	20
Total	258

Section B, measured 1,500 feet due north of Antler Peak

Conglomerate, sandstone, shale, poorly exposed.	205
Sandstone, red, containing a lenticular limestone member as much as 4 feet thick, 40 feet above the base. Sandstone and conglomerate, reddish brown. Sandstone shaly and containing lenticular limestone bed 4 feet thick at top of unit.	60
Total	265

Section C measured due east from 1/4 cor. between secs. 3 and 4, T. 31, N.R. 43 E.

Break in Section

Limestone, light gray with abundant fossil fragments including crinoid stems, brachiopods, and gastropods.	6
Conglomerate, siliceous shale, sandstone. Siliceous shale red, green, and gray, locally calcareous. Conglomerate, generally leached gray; massive to thick bedded. Sandstone, red, fine to coarse, in beds 2 to 24 inches thick; thin bedded near top. Sandstone grades laterally into siliceous shale and pebbly sandstone into conglomerate.	63
Limestone, reddish gray, mottled red brown in places in medium to thick beds with wavy bedding; grades into reddish-yellow shale and sandstone at base and top; contains Productus, Ozawainella, and Chaetetes.	8

	Feet
Conglomerate and sandstone. Conglomerate, reddish brown, medium to thick bedded; pebble and cobbles chiefly gray, red, and brown chert, some quartzite. Well bedded for most part; generally good sorting. Sandstone, pale to dark reddish brown generally thin to medium bedded; locally calcareous. Sandstone and conglomerate interfinger along the strike.	97
Conglomerate, reddish brown, thick bedded. Cobbles, pebbles, and boulders of gray, green brown, and white chert, quartzite, and sandstone. In places contains sandy partings and layers of thin-bedded reddish-brown and green sandstone. Generally well bedded, but not well sorted.	147
Conglomerate and sandstone. Conglomerate boulders, cobbles, and pebbles of sandstone, limestone, greenstone, chert, and quartzite. Boulders up to 3 feet diameter, commonly angular, poorly sorted. Matrix pebbly sandstone; cement calcareous, ferruginous and argillaceous. Generally well bedded; locally shows torrential and cross bedding. Sandstone, reddish brown, lenticular bedding; in places calcareous, shaly. Conglomerate and sandstone.	68
Conglomerate, medium to dark reddish brown, thick bedded to massive. Conglomerate contains boulders, cobbles, and pebbles of sandstone, quartzite, chert, limestone, and greenstone. Boulders up to 3 feet diameter, commonly angular to subangular. Torrential and cross bedding common; sorting poor except in pebble conglomerate. Reddish brown sandstone matrix with calcareous, ferruginous, argillaceous cement.	86
Harmony formation Total	475

Stratigraphic relations.-- The Battle formation rests unconformably on rocks of the Scott Canyon, Valmy and Harmony formations. The unconformity is marked by angular discordance throughout the quadrangle, for the Battle formation in most areas dips gently westward, and the older units were highly folded and thrust faulted prior to the deposition of the Battle formation. (See plates 11A, 12.)

Where the Battle formation rests on rocks of the Harmony formation, the lower beds contain a large proportion of boulders of sandstone in a matrix of sand grains also derived from the Harmony formation. In addition, pebbles of greenstone, quartzite, chert, and jasper, presumably derived from the Scott Canyon and Valmy formations, and pebbles of red and yellow shaly limestone of unknown origin are also present. The source of the limestone pebbles is of considerable interest for no beds of similar limestones are now known in the region. The middle conglomerate beds contain a greater proportion of chert and quartzite pebbles, and the pebbles of the upper beds are almost entirely chert and quartzite. This indicates that either the sources of rocks other than chert and quartzite were eroded as time went on, or that they were gradually covered by the overlapping conglomerate beds.

Where the Battle formation rests on rocks of the Scott Canyon and Valmy formations in the northwestern part of the quadrangle the basal beds contain chert and quartzite pebbles derived from these formations. The upper beds locally contain gray crystalline limestone pebbles of unknown origin, some of the pebbles contain fossils, but they are too poorly preserved for age determination.

The Battle formation is overlain by the Antler Peak limestone with apparent conformity at the type locality. As the contact is traced northwestward, however, it is apparent that the Battle formation thins, either because of non-deposition, or because of erosion prior to the deposition of the limestone. It is certain that the Battle formation was originally variable in thickness for in Edna Mountain, about 8 miles east of Golconda on U. S. Highway 40, pebble conglomerates interbedded with limestones aggregate about 400 feet in thickness. The basal unit is a lenticular conglomerate 20 to 100 feet thick which is referred to the Battle formation. The overlying limestone and interbedded conglomerates are probably equivalent to the middle and upper parts of the Battle formation at Antler Peak, but because of the difference in lithology it has been treated as a distinct formation.

It is likely that erosion prior to the deposition of the Antler Peak limestone was also a factor in causing variations in thickness of the Battle formation. On the western side of Edna Mountain at a point 6 miles east of Golconda, the Antler Peak limestone rests directly on folded and eroded strata of Cambrian age, indicating complete removal of strata of the Battle formation and Highway limestone which may have been deposited there. Locally a limestone conglomerate that was derived from the underlying limestone is present at the base of the Antler Peak limestone.

In Copper Basin the Battle formation does not exceed 150 feet in thickness. Within short distances it thins abruptly and is locally absent so that the Antler Peak limestone rests directly on the Harmony formation. Here too, it is likely that the thinning is due to erosion prior to the deposition of the limestone, but non-deposition may also have been a factor.

Age.--The age of the Battle formation is based on determinations by Lloyd Henbest. Fossils were collected in the type section on the west side of sec. 3, T. 31 N. R. 43 E. about 400 feet above the base. The diagnostic fossils include Chaetetes sp. and Ozawainella. Both of these are considered to be of Des Moines (lower Pennsylvania) age. Productids and crinoid stems are also found but are not diagnostic. The lower beds of the overlying Antler Peak limestone contain fossils of upper Pennsylvanian age.

Origin.--The Battle conglomerate is a striking and distinctive lithologic unit. Hague and Emmons (1899, p. 688) referred to it as follows: "A prominent stratum consists of a coarse conglomerate of quartz and jasper pebbles, held firmly together by a binding material of fine ferruginous sand". Lawson (1913, p. 328) writes as follows:

> "Resting unconformably on the upturned edges of these strata (Harmony formation) and occurring chiefly as a mesa-like cap on various hilltops, is a later formation composed of angular fragments of the underlying rocks, but so thoroughly silicifed and cemented that it is one of the hardest and most resistant formations of the district... Except for the fact that it is thoroughly cemented and indurated, the rock is very similar to the detritus which flanks the margins of the mountain in the form of alluvial fans. There can be little doubt but that the formation is the remnant of an alluvial fan deposit spread over the region in the remote past....I hate to call the rock a conglomerate because that...suggests an erroneous conception of the mode of deposit and climatic conditions which determined that mode...I propose that this and similar rocks be known as fanglomerate....In defining the term I must first make clear that it is not intended to include the finer sediments on the lower flanks of alluvial fans, but only the coarser deposits in the upper part....In many alluvial fans the constituent blocks are of extraordinary size near the apex and sporadic blocks several feet in diameter are by no means uncommon far down the slope where the size of the fragments may be less than an inch....Apart from its interest as a type of sedimentary rock the fanglomerate of Battle Mountain is significant of the existence of conditions in the far past similar to those which prevail in the Great Basin today. Those conditions are bold relief and aridity... the immediate result of acute diastrophism."

Thus the term, "fanglomerate" came into existence, and it has been used widely since then to designate deposits which come more or less within Lawson's definition. Judging from Lawson's description, he visited only localities in Copper Basin where the Battle formation is exposed. Here it is medium to thick bedded conglomerate with subangular to rounded chert, sandstone, and some limestone cobbles and pebbles in a silicified sandy matrix. The conglomerate is for the most part well bedded, and channelling, cross bedding, and similar features are rare.

Lawson's interpretation of this rock as a fan deposit is open to question. It does not resemble the material in the present alluvial fans of the region in texture, structure, and general appearance. Fan gravels in north-central Nevada are made up of poorly sorted materials dumped heterogeneously at the range fronts by intermittent streams. Cross bedding, channeling, current bedding, and abrupt changes in lithology are characteristic and everywhere present. (See plates 14, 15A.)

Study of the type section of the Battle formation at Cow Canyon where it is thicker and less altered than at Copper Basin gives a better idea of its origin. A summary of the type section follows: The lower beds comprise about 154 feet of thick-bedded, poorly sorted, boulder, cobble, and pebble conglomerate. Above these beds are some 244 feet of rather well sorted cobble and pebble conglomerates with interbedded sandstone and shale. The remaining 300 feet of the formation consists of interbedded limestone, calcareous shale, pebble and granule conglomerate, sandstone, and shale.

Some idea of the conditions of deposition can be obtained from the textures and structures of the sediments. In the lower beds the rock fragments are not angular but are mostly subangular and subrounded.

Cross bedding, current bedding and channelling are present in places, but are characteristic of only a few beds. On the whole the bedding is uniform and tends to be gradational from one bed to another without abrupt changes. The sorting is poor in the lowest beds, and becomes fair to good stratigraphically upward. (See plates 11B, 12, and 13). These beds were probably deposited by streams of high competency on a lowland adjacent to a rugged upland. The nature of the lowland is speculative but it may have been a piedmont or broad delta plain.

The source area was comparatively close judging from the coarseness of the material and relative fragility of the limestone, greenstone, and sandstone fragments. In addition, it may be inferred that in the source area the relief was high for unweathered rock was furnished to the streams. The climate in the upland was probably hot and humid with seasonal rainfall (lateritic conditions) as is indicated by the iron oxide cement of the conglomerate. (Krynine, 1938, p. 96.) The conglomerates exhibit some of the features of sediments related to faulting, (Longwell, 1937, p. 440) and seem comparable to some of the Triassic sediments in New England.

As one goes up the section of the Battle formation into the middle and upper beds the similarity to present day fans becomes even less evident. The clastic beds clearly interfinger with fine-grained marine sediments indicating that a seaway had reached the present site of Galena Canyon, and marine conditions prevailed at times during the deposition of the middle and upper beds. The overlying Antler Peak limestone was deposited entirely under marine conditions.

Merriam and Berthiaume (1943, p. 149, 165) noted a boulder conglomerate in the Pennsylvanian of central Oregon which was associated with plant-bearing deposits as well as marine facies. They considered that the conglomerate was deposited on a delta plain by streams of great carrying power during flood periods; crustal instability caused oscillation from subaerial to estuarine or marine conditions. Similar oscillations probably took place in the basin where the Battle formation was deposited.

As the Battle formation is largely of marine origin it does not seem desirable that it be known as the type "fanglomerate." It is therefore suggested that some more appropriate formation be selected as the type fan - glomerate. Perhaps one of the Tertiary or Quaternary formations of the southwest would fulfill the requirements listed in Lawson's original description (see page 32).

Antler Peak limestone

Occurrence.--The name Antler Peak limestone is here applied to the limestone beds that make up Antler Peak and crop out in a northwest trending belt through the center of the range, in Copper Basin, and in a small area southeast of Copper Canyon mine. Most of the formation consists of limestone, sandy limestone, and shaly limestone.

Because of the varying resistance to erosion of the members of the Antler Peak limestone, the outcrops show step-like breaks, and slopes cut on the limestone show alternating treads and risers. Where the dip of the beds parallels the slopes, generally the treads are wide and the risers are comparatively low. Where the beds are horizontal or dip into the slopes the treads are narrow and the risers range from a few feet to 50 feet in height. Locally, as on the southeast slope of Antler Peak, faulting together with steeper than average dips have combined to produce impressive cliffs a hundred feet or more high. (See pl. 5). The best exposures and most complete section are on Antler Peak and this section is therefore designated the type section.

The outcrops of Antler Peak limestone occur in two belts parallel to the underlying Battle formation but are less continuous. The westernmost belt extends from Galena northward to Antler Peak, then northwestward to the head of Cottonwood Canyon, a distance of about 5 miles. Two isolated exposures occur to the south in Copper Canyon, one on the east side of the canyon near the range front, and the other at Nevada Mine. Two more exposures occur in the northern part of the range near the Marigold mine. Elsewhere the limestone is cut out by the overriding Golconda thrust fault, or by later normal faults. The eastermost belt is on the east side of Copper Basin. The exposures extend northward underneath the rhyolite flows that cap Elephant Head for three miles and form a belt nearly 2 miles wide at the Copper King mine, extending off the quadrangle to the edge of the range.

Stratigraphic relations.--The Antler Peak limestone at the type locality rests with apparent conformity upon the Battle formation. Elsewhere the two formations appear to be conformable, but it is likely that a period of erosion intervened before deposition of the limestone. The evidence for this is chiefly in Edna Mountain where the Antler Peak limestone rests successively upon the Battle formation and an unnamed limestone and Cambrian and Ordovician rocks. Locally a thin basal limestone conglomerate is present. The basal limestone beds (units D and E) are present in Edna Mountain, and can be identified by the presence of a characteristic limestone with brown-weathering shaly parting which contains abundant remains of Triticites pygmaeus.

In the Sonoma Range (Ferguson, Muller, and Roberts) the Battle formation is absent and the limestone rests directly on the Harmony formation. The basal beds of the limestone appear to be absent in this area, but it is thought that the F unit is the lowest bed on the west side of Clear Creek.

Section at Antler Peak.--This is designated the type section of the Antler Peak limestone. (See plates 5 and 6.) About two-thirds of the section given below was measured on the south slope of the peak and the upper third on the west side of the peak. The beds are listed in descending order.

Section of the Antler Peak limestone on Antler Peak

Erosion surface

Unit		Feet
O	Limestone and shaly limestone, banded light gray to dark gray and buff; and weather to brown, brownish gray, and yellowish brown. Lower 60 feet of beds characteristically have striped appearance; contain abundant small brachiopods and pelycypods which weather in relief. Interbedded chert conglomerate and intraformational limestone conglomerate up to 40 feet thick near middle of unit; local cross bedding in sandy and shaly layers.	155
N	Limestone, light gray, thick bedded to massive, sandy partings which weather in relief; upper beds sandy and pebbly in places. Lower beds form cliff as much as 80 feet high.	140
M	Limestone, gray, sandy and conglomeratic, generally cross bedded. Basal layers contain well rounded chert and quartzite granules and pebbles in sandy limestone matrix. Upper beds sandy and shaly, form smooth slopes.	40
L	Limestone, dark grey, with gray sandy limestone in central part. Wavy bedding. Contains Syringopora sp. in upper part. In places forms cliff.	25
K	Shale, light greenish gray and brown, shaly limestone at base. Forms smooth slope above limestone; in places forms nearly flat terrace.	20

Unit		Feet
J	Limestone, gray, thin-bedded, with thin cherty bands at top. Lower 4 feet sandy limestone, less resistant than upper.	15
I	Limestone, lower 20 feet thin-bedded, dark gray, cherty with brown-weathering shaly limestone at base; chert concertions, small and irregular locally. Upper 50 feet gray, brown-weathering, shaly and sandy limestone; platy parting in places. Generally forms cliffs made up of many narrow treads and steep risers.	70
H	Limestone, thin to medium bedded, gray, brown-weathering. Generally forms smooth slope.	10
G	Limestone, medium to thick bedded, dark blue gray. Forms cliffs up to 40 feet high. Wavy bedding, in places containing shaly partings 4 to 12 inches apart. Contains chert nodules scattered throughout the bed. Silicified Caninia bed at base.	45
F	Limestone, medium to thick bedded, dark gray. Shaly parting 6 inches thick at base. Chert nodules and layers occur in some beds, but are nowhere abundant. Syringopora and Caninia 5 feet below top. Beds form irregular outcrops.	20
E	Limestone, thin to medium bedded, light gray to brownish gray, shaly. Thin beds generally have shaly partings which weather brown. Near center of bed fusulines (Triticites pygmaeus) and associated fossils abundant. Wavy bedding; chert nodules in upper part. Forms smooth slope, broken by minor steps.	25
A-D	Limestone, brownish gray, brown-weathering, thick-bedded interbedded with sandy limestone. Upper beds show cross bedding in places. Two beds at base contain abundant Caninia-type corals. Forms prominent ledge.	60
	Battle formation Total	625

The sections in the other occurrences of the Antler Peak limestone in the western belt are so incomplete that none was measured. The general lithology and faunas of these occurrences are similar to those of the type section indicating that the conditions of deposition were uniform throughout the belt.

Section in Copper Basin.--In the Copper Basin area, the Antler Peak limestone differs from the type section in some ways. No detailed section has been measured here, but careful comparison of the members disclosed that the lowest bed is the unit L or K of the section at Antler Peak; unit M is well developed in Copper Basin and so are the overlying units N and O. Higher beds than the O bed are present just north of the edge of the quadrangle, for the O bed grades into shaly limestone and shale not found in the section at Antler Peak. These upper shaly beds weather buff to darker shades of brown. The section in Copper Basin as given by H. G. Ferguson is as follows:

Section in Copper Basin

		Estimated thickness in feet
Q	Limestone, gray, thin-bedded and shaly in places; irregularly mottled with chert.	300
P	Limestone, brown, shaly; poorly exposed.	100
O	Not exposed. Float of bluish-gray shaly quartzite and shale.	50
N	Limestone, thin-bedded, gray with brown chert lenses and layers. Upper part poorly exposed, but calcareous sandstone and chert, and quartzite conglomerate float noted.	300
L	Not exposed	200
K	Limestone, gray and brown, thin-bedded; sandy limestone and calcareous shale in lower part. Irregular brown chert layers abundant near top.	500
J	Limestone, brown, shaly. Thin-bedded.	50
I	Limestone and dolomite (?), gray, cherty near top.	100
H	Limestone, brown, blocky, and thin-bedded; some calcareous shale interbedded	50
G	Limestone, shaly; poorly exposed	300
	Battle formation	

Age.— The Antler Peak limestone was first designated as Carboniferous geologists of the 40th Parallel Survey (King, 1877, p. 670). In Willow Creek the following forms were recognized.

	Equivalent Modern name
Productus semireticulatus	Dictyoclostus semireticulatus
Productus prattenianus	Linoproductus prattenianus
Eumetria punctulifera	Hustedia mormoni
Athryis incrassata	Composita sp.

About 100 feet below the summit of Antler Peak the following fossils were collected by King.

Fusulina cylindrica
Campophyllum sp. ?

In 1940, James Steele Williams visited the Antler Peak quadrangle with the author and collected fossils from several localities. Mr. Williams writes as follows:

> "Other duties have prevented me from making more than a cursory examination of most of these collections, and I have not been able to study others at all. I have recently started on a more comprehensive study of all the collections from this and adjoining areas and hope to have more definite data soon.
>
> Soon after I first visited this general region in 1938 on the basis of the study of a limited number of collections I agreed with Mr. Henbest in assigning the age of the formation as upper Pennsylvanian. Later in 1945 I noted in a memorandum to Mr. Ferguson that I had in mind that the fauna may be as young as Wolfcamp in age. The age designation will have to rest in this uncertain category (Pennsylvania (?)) until I have had more time to study the fauna.
>
> The fauna has several species and genera of productoid brachiopods, several species of spiriferoid brachiopods, chonetids, and other brachiopods. Many of these belong to new or little known species, and I should not like to attempt to name them without more study. In addition, there is a considerable coral element in the fauna. Miss Helen Duncan, who is studying it, has recognized large Caninia, syringoporoids, and other types. Fusulinids are also very common, and Mr. Henbest has found time to report on only a relatively few of them.

The faunal facies and some of the species remind me, as I noted in 1940, of some of the Alaskan collections from beds that have been called Permian there. Resemblances to Russian species and faunules have also been noted. Further and more detailed conclusions must await further progress toward completion of the extensive investigations that I am making of the late Pennsylvanian and Permian formations and faunas of the northwestern United States and Alaska."

Mr. Williams' tentative comparison of the Antler Peak fauna with fauna of Alaska and Russia opens up an interesting line of speculation as to the possible extent of the Pennsylvanian basin in north-central Nevada and its possible connections northward with the Cordilleran geosyncline. Eardley (1947, fig. 2) shows a Pennsylvania sea covering most of Nevada and western Utah. This idea may require some modification if the absence of forms of the Rocky Mountains is significant. There may not have been a connection eastward across Nevada with Pennsylvanian seas in Utah; deposition may have taken place in distinct basins separated by a land barrier east of Battle Mountain.

Lloyd G. Henbest has examined fusulinid collections from the Antler Peak limestone in Edna Mountain and at the type locality. The collections contain a large number of very small Triticites apparently T. pygmaeus, Dunbar and Condra. According to Henbest fusulinids of this kind are generally restricted to the middle or lower part of the Missouri series in Kansas, Nebraska, Missouri, Iowa and Wyoming. They are also found in the Gaptank of the Glass Mountains and possibly in the Magdalena at Jemez Springs, New Mexico. Other more highly evolved species, found somewhat higher in the section, are not earlier than middle or upper Missourian and more likely Virgil series of the Pennsylvanian. The fusulines therefore are of upper Pennsylvania age. Henbest stated, however, that they seem to differ from the mid-continent forms and as they may belong to the Pacific province where the fusulinid successions are not well understood; the exact age significance remains uncertain.

The limestones and dolomites in Copper Basin are in part equivalent to the upper beds at Antler Peak, and the fauna in the Copper Basin is similar. Mr. Williams noted that the limestones and dolomites in the upper beds contain more clay and silt, and that the fauna is dwarfed, but reports that the collections are about the same age or slightly younger.

Relations to underlying formations--In Battle Mountain the Edna Mountain formation rests without noticeable angular unconformity on the Antler Peak limestone, but on the north flank of Edna Mountain the limestone was almost completely eroded and it lies on folded Cambrian rocks. (Ferguson, Roberts, and Muller.) In the Osgood Range, fanglomerate(conglomerate ?) is present at the base of a unit tentatively correlated with the Edna Mountain formation. (Hobbs, 1948.)

Age.--The shaly limestones of the Edna Mountain formation near the Nevada mine contain poorly preserved brachiopods. James Steele Williams has compared this fauna with the fauna of the Edna Mountain formation and considers both of them approximately equivalent in age to the Phosphoria formation of Idaho and adjacent states, although they contain few species in common.

Edna Mountain formation

Occurrence.--The Edna Mountain formation is named for Edna Mountain in the Golconda quadrangle. (Ferguson, Roberts, and Muller.) The formation consists principally of calcareous sandstone. It is exposed in only a few places in the Antler Peak quadrangle where it crops out just below the Golconda thrust fault. The principal exposures are in Galena Canyon at several places along the west side of the canyon, at the Nevada mine, and on the northwest flank of the range a mile southeast of the Cyarbide Ranch.

Lithology and thickness.--The rocks assigned to the Edna Mountain formation in this area are interbedded shale, shaly limestone, sandstone, and chert conglomerate aggregating about 100 feet in thickness. The shale is commonly gray, brownish gray, or greenish gray and weathers gray and buff. In most places the shale is sandy and grades laterally into shaly sandstone. Chert conglomerate, containing pebbles ranging from 1/4 to 1/2 inch in diameter of black, gray, brown, and green chert, is a characteristic member near the top of the formation. In places the conglomerate is as much as 20 feet thick, and a half mile south of Galena the conglomerate forms a reistant bed that crops out prominently. The pebbles and granules are typically rounded to well rounded and are in siliceous or calcareous matrix. Although this conglomerate resembles pebbly units in the upper part of the Antler Peak limestone, it contains a much greater proportion of pebbles to matrix.

Regarding the fauna of the Edna Mountain formation Mr. Williams reports as follows:

"The best collections from the Edna Mountain formation came from four localities (8725, 8726, 8727, amd Muller 7/24/41); all of these localities are close to Highway 40 about 5 miles east of Golconda. The fauna, as shown by these collections contains Neospirifer pseudocameratus (Girty) in abundance. The individuals show a very wide range of variation, and more than one species may be represented. Also present in the fauna are many individual specimens of a Chonetes that may be a variety of C. ostiolatus (Girty), a very fragmentary linoproductid identified very tentatively as Linoproductus cf. L. eucharis (Girty), a large Hustedia represented by molds, which is probably H. phosphoriensis of Branson, and also represented by molds of one kind or another, forms very tentatively identified as belonging to Wellerella ?, Cleiothyridina ?, a large Composita, Juresania ?, Rhynachopora ?, and Conocardium?. There is also a mold of small Punctospirifer which cannot be specifically identified but which has some resemblances to a young P. pulcher (Meek).

The fauna as shown by the above mentioned collections, though lacking good representatives of several important elements of the Phosphoria fauna, is nevertheless more closely related to this fauna and to its equivalent, the Gerster formation, then to any other faunas of the Rocky Mountains.

The age is therefore thought to be Phosphoria. The resemblances are slightly more with the lower part of the Phosphoria than with the upper part, but it would be unjustified to attempt to refer the fauna definitely to any part of the Phosphoria. In fact, it might be slightly older than typical Phosphoria."

A few corals that were collected from the Edna Mountain formation at locality 8726 were studied by Miss Helen Duncan, whose remarks concerning them are as follows:

"The specimens are simple column-bearing horn corals, mostly molds or crushed specimens. The genus might be Stereostylus, which is apparently not uncommon in the Pennsylvanian and Wolfcamp, and probably will be found to range into beds of Leonard or younger age, though it has not been reported hitherto from beds so young."

The Edna Mountain formation, however, is younger than the Antler Peak limestone, and the interval between the two formations may represent a distinct stratigraphic break. During the early Permian this part of Nevada probably remained at or near sea level, but local warping and uplift above sea level caused erosion of part of the Antler Peak limestone in most places, and locally much of the Battle formation was removed. The total uplift is not known, but it may have been 1,500 feet and possibly more. The erosional unconformity between the Antler Peak limestone and Edna Mountain formation may reflect the orogeny in the upper plate facies which took place in the Permian (see page 96).

Upper plate sequence

The upper plate facies includes the Pumperhickel and Havallah formations which are on the upper plate of the Golconda thrust. In China Mountain, Golconda quadrangle (Ferguson, Roberts, and Muller), rocks belonging to the Havallah formation are overlain unconformably by volcanic rocks of the Koipato formation. The Koipato formation is of Phosphoria (Permian) age and is overlain unconformably in turn by Triassic rocks. The Koipato formation is roughly equivalent in age to the Edna Mountain formation of the lower plate, but the two formations accumulated in entirely different areas. On the east side of China Mountain the Koipato formation pinches out and is overlapped unconformably by the Triassic; presumably the Triassic rocks extended eastward and also covered the upper plate in Battle Mountain at one time, but now they have been stripped by erosion, and no Triassic rocks are known in northcentral Nevada east of Battle Mountain up to the East Humboldt range (S. W. Muller, personal communication).

No fossils have been found in the Pumpernickel formation, but it is considered to be of Pennsylvanian (?) age as it underlies the Havallah formation with apparent conformity.

Pumpernickel formation

The Pumpernickel formation was named from exposures west of Pumpernickel valley on the east side of the Sonoma Range (Ferguson, Muller, and Roberts). Here it is composed principally of interbedded chert, argillite, and greenstone, and is estimated to be 5,000 or more feet thick.

The Pumpernickel formation is on the upper plate of Golconda thrust, and because its lithology is entirely different from any formation of comparable age in the lower plate, it evidently was thrust from a great distance to its present position.

Occurrence and lithologic character.--The Pumpernickel formation extends from the south-central edge of Battle Mountain in a belt a mile to two miles wide north-northwest to the headwaters of Trenton Canyon. Here it is cut out for a half mile by intrusive granodiorite and by a downfaulted segment of the Battle formation, but beyond these it continues northwestward to the range front.

Southward from the range front in Trenton Canyon a faulted sliver continues to Mill Canyon. Northward from Trenton Canyon the belt narrows after crossing Cottonwood Creek and is only a few hundred feet wide at the Marigold mine. Pleistocene and Recent alluvium cover the extension of the Pumpernickel formation north of the range.

The Pumpernickel formation is cut diagonally by the Golconda thrust, and consequently only a part of the section is exposed in the area. For this reason, and because of the similarity of the beds throughout the section no detailed section was measured. The thickness is estimated to be at least 5,000 feet and may be considerably more. The most striking exposures, however, are in the ridge west of Copper Canyon, and on the slopes west of Willow Creek at the end of the road in sec. 32, T. 31 N., R. 43 E. Generally the argillites weather to smooth slopes, and the thicker chert beds form prominent outcrops.

The Pumpernickel formation can be divided into two principal parts. The lower part consists largely of interbedded argillite and chert and is estimated to be about 3,000 feet thick. These rocks make up the ridge between Copper Canyon and Willow Creek, and extend as far north as the 7,130 summit on the ridge south of Antler Peak. A combination of normal and thrust faulting cuts out the lower part of the formation here, and the upper beds, chiefly argillite, with minor amounts of chert, continue north-northwestward.

The lowest beds of the Pumpernickel formation in the quadrangle are chert and argillite exposed in the ridge west of Copper Canyon. (See plates 26 and 27.) Near the intrusive quartz monzonite at the Copper Canyon mine the chert has been recrystallized to fine-grained rock resembling quartzite, and the argillite to hornfels. The metamorphism dies out rapidly and is hardly noticeable a half mile away from the quartz monzonite.

Typically the cherts of the Pumpernickel formation are thin- to medium-bedded with wavy and lenticular bedding. Lithologic units also seem to be lenticular for they can rarely be traced more than a few thousand feet before they grade into argillaceous rocks. The cherts are commonly thin-bedded and have shaly partings. The chert beds generally range from a fraction of an inch to a foot or even two feet in thickness, but the average thickness of individual beds is 2 to 6 inches.

Study under the microscope has shown that the cherts of the Pumpernickel formation contain consistently more clastic material than the cherts of the Scott Canyon formation. Clastic grains are generaly present disseminated throughout the rock and concentrated in shaly partings. (See plate 25). Their grain size ranges from .02 to .08 mm and averages about .05 mm. These grains of quartz are always angular and are in the silt and very fine sand size ranges. (See plate 26.)

All gradations can be found between argillite and chert. In the argillites the fragments are principally quartz and calcite together with small amounts of heavy minerals cemented with argillaceous material. The clastic calcite is generally rounded, but some of the grains are subhedral and show rhombohedral faces. In addition to these minerals, fresh oligoclase grains were noted. These grains are imbedded in a groundmass which is nearly isotropic, but contains cryptocrystalline to finely crystalline material. The origin of this material is not known, but in part it is chert and with diminution of fragmental material the rock would grade into chert. Wisps of sericite or muscovite and a green chloritic material also occur in the groundmass. These minerals were probably partly of clastic origin, but the chlorite was probably formed by alteration of biotite.

Coarse sandstone layers are in places interbedded with the chert and argillite. One persistent layer 8 to 12 inches thick, is exposed on the ridge west of Copper Canyon. The sandstone is brown and shows prominent clastic mica flakes; it bears a striking resemblance to the coarse sandstone of the Harmony formation. Under the microscope the rocks are seen to contain, in addition to quartz, abundant fledspar grains and calcite. The feldspar is largely orthoclase and microperthite with some plagioclase and although these minerals are on the whole fresh they are partly replaced by calcite. The source of the feldspar is of considerable interest for this layer is the only lithologic type of the Pumpernickel formation whose material is usfficiently distinctive to permit inquiry as to the source. Two possibilities immediately come to mind; one, that the granitic terrain from which the Harmony formation was derived was again exposed to erosion; the other, that the Harmony formation itself was being eroded and the feldspars and associated minerals were retransported to the basin in which the Pumpernickel sediments were deposited. The second possibility seems more likely for it will be recalled that the Harmony formation was folded and beveled prior to Battle time (lower Pennsylvanian) and the lower part of the Pumpernickel formation may have been deposited contemporaneously with the Battle formation in a separate basin near enough, possibly, to have had the same source area.

The upper part of the Pumpernickel formation is best exposed in the bottom and on the western side of the valley of Willow Creek. The upper beds are estimated to be about 2,000 feet thick in this area, and consist chiefly of argillite, siliceous argillite, and chert. The argillite is generally dark red, locally grading into purplish red and brownish red, or dark green. The argillite grades into red and green siliceous argillite and chert along the strike and down dip. Specimens of the argillite and chert were studied microscopically, analyzed chemically, and, are described in more detail on pages 54 and 55.

Near the top of the Pumpernickel formation, greenstone flows and associated pyroclastic rocks are a distinctive unit. In Willow Creek this unit is thin, probably not more than 20 feet thick, but on the north side of Timber Canyon (sec. 1, T. 32 N., R. 42 E.) it is probably 50 feet thick and near the Marigold mine it is more than 100 feet thick. To the west in the Sonoma Range, volcanic rocks make up a much larger proportion of the Pumpernickel formation, and it is possible that Battle Mountain is near the eastern edge of the major volcanic activity.

It is interesting to speculate on the conditions of the deposition of the Pumpernickel formation, although little is yet known concerning the extent of the basin where it accumulated. Worm trails are abundant throughout the formation in the chert and argillite. Ripple marks, both current and symmetrical types, are common, and together with mud cracks indicate that the rocks were deposited in relatively shallow water. An abundant supply of silt and clay size particles was brought into the basin, but the source area must have been low or far removed most of the time. The local sandy beds may indicate minor disturbance in the basin or nearby areas.

Age.--No fossils have been found in the Pumpernickel formation, and its age is consequently unknown. As it conformably underlies the Havallah formation whose lower beds are probably of Wolfcamp age, the Pumpernickel formation is considered to be Pennsylvanian (?). A more precise determination must await discovery of determinable fossils.

Havallah formation

Occurrence and Lithologic character.--The Havallah formation underlies the west side of Battle Mountain and extends northward along the foothills continuously, except for a gap near Trenton Canyon, to the northwestern corner of the quadrangle. The type section has been designated in the Tobin Range near Hoffman Canyon (Tobin and Mt. Moses quadrangles, Ferguson, Muller and Roberts) where the thickest, though incomplete section, is exposed. Thus far determinable fossils have been found only in the lower part of the formation in the Antler Peak quadrangle.

The rocks that make up the Havallah formation are distinctive, but individual beds may resemble individual beds of the Pumpernickel, Scott Canyon, or Valmy formation, for all these formations contain a large proportion of thin-bedded chert, argillite, and quartzite. The Havallah formation is characterized, however, by alternations of all these rocks in contrast to thick units of a single type of rock as in the other formations.

For convenience in description the Havallah formation in Battle Mountain is divided into three members, a basal member composed of interbedded quartzite, quartzite conglomerate, and sandy shale; a middle member of interbedded chert, shale, and calcareous quartzite; and an upper member of interbedded chert, shale, limestone, and quartzite. These members were not differentiated in the field and no detailed section has been measured. The estimated thickness in Battle Mountain is 5,000 feet, but the section may be considerably thicker in the type section Tobin Range where Ferguson estimates over 10,000 feet of beds.

The basal member of the Havallah formation rests with apparent conformity on chert and shale of the Pumpernickel formation. The contact is not everywhere definite, but in the field was usually taken at the first prominent sandstone or quartzite bed. In Battle Mountain the upper part of the Pumpernickel formation contains a thin greenstone flow or layer of greenstone pyroclastics 50 to 100 feet below the contact which was a convenient marker bed that aided in mapping the contact.

The lower member of the Havallah formation is well exposed on the west side of Willow Creek and in the foothills south of the Marigold mine. The basal beds are coarse sandstones and quartzite, locally pebbly and in places conglomeratic. They are medium to dark gray and weather brownish gray, and are interbedded with argillites that weather rapidly, leaving the sandstones standing in bold relief. Under the microscope the sandstones and quartzites are seen to contain fragments of biotite, muscovite, orthoclase, plagioclase, microcline and quartz similar to the fragments of the Harmony formation, but the feldspars are less abundant. Pebbles, which are scattered throughout the beds and in places make up thin layers, are largely chert with some quartzite. The sandstones near the granodiorite of Trenton Canyon are metamorphosed to quartzite; the metamorphism consisted chiefly in crystallization of the rock and bleaching to light gray or white.

The quartzites and sandstones of the lower member appear to range from 400 to possibly 600 feet in thickness; above these beds shale predominates and interbedded cherts appear.

The middle member of the Havallah formation is composed of interbedded chert, shale, and calcareous quartzite. The units are thin for the most part; they rarely exceed 25 feet, and probably do not average more than 10 feet in thickness. The cherts and shales are generally light brown, green, purple or gray. They are similar to the cherts and shales of the Pumpernickel formation and cannot be definitely distinguished in the field, but are prevailingly lighter in color. The cherts and shales are interbedded with calcareous quartzite, however, which is distinctive. The quartzite is fine grained and is generally medium gray to buff. It weathers to yellow or brown, but in places has a dark-brown coating of iron oxides. Under the microscope the grain size is seen to be commonly less than 0.10 millimeter, and averages about 0.05 millimeters. The relative proportions of quartz and calcite are variable, but they are generally present in approximately equal proportions. The quartz grains are angular, and locally are cemented by fine-grained or chalcedonic silica. The calcite grains are anhedral to subhedral; they were deposited as clastic grains, and some show secondary growth after deposition.

The upper member of the Havallah formation consists of interbedded chert, shale, limestone, dolomite, quartzite and calcareous quartzite. The chert and shale are similar to the chert and shale of the middle member, but the limestone and dolomite are distinctive . The limestone and dolomite are generally thin bedded and grade laterally into shale and chert. Commonly they are light to medium gray and fine- to medium-grained.

Age.-- The only determinable fossils found thus far in the Havallah formation have come from the lower part of the formation in the southwestern part of Battle Mountain. They consist principally of fusulinids which were examined by Lloyd Henbest and described as follows:

Collection 390. Rocky Canyon, sec. 12, T. 31 N., 42 E.
Two minute species of an early stage of Perafusilina or possibly late forms of Schwagerina are present. These are not older than late Wolfcamp and probably not younger than early Leonard.

Collection 520. Rocky Canyon, sec. 12, about 200 feet below 390. The fusulinids in this sample are mostly abraded and fragmentary. They are definitely Permian and resemble those in collection 390 except that they seem (with considerable uncertainty) to be Schwagerina and Wolfcamp age. Without considerable further preparatory work, I couldn't say that they might not be Leonard.

Collection 394. Rocky Canyon, sec. 24, T. 31 N., R. 42 E. possibly equivalent to collection 390. This contains the same fusulinids and Osagia-like algae that are found in 390, but I cannot add more specific information as to whether this horizon is late Wolfcamp or is Leonard. The age is definitely Permian, and almost definitely not older than middle Wolfcamp and not younger than Leonard.

According to these determinations the lower part of the Havallah formation would therefore appear to be of Wolfcamp and Leonard (?) age.

Worm tracks and unidentified algae are found in many beds in the upper part of the formation but are of no value in age determination.

In the northern part of the Tobin Range at China Mountain the Havallah formation is overlain with angular unconformity by the Koipato formation. About 60 miles west of China Mountain Koipato strata near Rochester have yielded Helicoprion (Wheeler, 1937), a shark of Phosphoria age. James Steele Williams (personal communication, 1949), considers the Koipato formation more or less equivalent to the Phosphoria formation, but suggests that the Koipato formation may be somewhat younger.

Origin of the siliceous rocks

In the Antler Peak quadrangle cherts make up a considerable part of the Scott Canyon, Valmy, Pumpernickel, and Havallah formations, and also occur in the Antler Peak limestone. The cherts in the Antler Peak limestone are principally nodules and thin discontinuous beds, but in all the other formations they constitute thick members, and form prominent units that form bold outcrops.

The aggregate thickness of the chert beds are not measured, but it is estimated that more than 5,000 feet of chert and siliceous shale must be present in the quadrangle. The origin of such a great thickness is one of the major problems in the study of sedimentation in the quadrangle, but time was not available to carry the study to satisfactory conclusion. The features that appear to be most significant in interpretation of the origin of the cherts will be summarized and discussed in the light of some of the prevailing theories for the origin of chert.

One of the outstanding features of the chert units in the Scott Canyon, Valmy, Pumpernickel, and Havallah formations is that the cherts are all similar in color, lithology, texture, and structure. Locally minor differences were noted, but none of the differences could be considered regional. The similarities which are most striking are the lenticular bedding, fine laminations, and shaly partings. All the cherts grade laterally into shale. Cherts which have similar composition, color, lithology, texture, and structure probably have similar origins.

During their long, complex geologic history the cherts have been compacted, deformed, and recrystallized. Under the microscope the cherts generally seem to be fine-grained chalcedony with varying amounts of clastic material, calcite, and clay minerals. Many of the cherts contain rounded bodies which appear to be organic in origin, and some of these can be identified as Radiolaria in dark field illumination. It is impossible to determine what proportion of the rock originally consisted of Radiolaria, but in some specimens studied the proportion may have been high.

In the Scott Canyon formation volcanic material makes up a considerable part of the higher layers. The pyroclastic layers grade into shales which also contain much material of volcanic origin. The cherts interbedded with the shales and volcanic rocks (see plate 19), also probably contain much volcanic material which is now recrystallized.

The Pumpernickel formation in the Winnemucca quadrangle (Ferguson, Muller, and Roberts), contains much volcanic material, but in Battle Mountain the only volcanic rocks are in the upper part of the formation. The volcanic rocks consist of greenstone and volcanic breccia; these rocks are interbedded with red, green, and purple argillite and chert. The origin of the argillite and chert is an interesting problem, for these rocks grade into one another along the strike. Representative specimens of the argillite and chert were analyzed so that they could be compared chemically. The analyses are as follows:

	1	2
SiO_2	75.28	89.15
Al_2O_3	10.22	3.45
Fe_2O_3	1.99	.58
FeO	2.24	2.19
CaO	.84	.24
MgO	2.00	1.05
Na_2O	.82	.22
K_2O	2.30	.53
H_2O −	.33	None
H_2O +	2.14	1.17
CO_2	.54	.11
TiO_2	.66	.22
MnO	.02	.03
BaO	None	.59
P_2O_5	.10	.04
S	.04	.14
	99.52	99.71
Less O=S	.02	.07
	99.50	99.64
Sp. gr. (bulk)	2.23	2.36
Sp. gr. (powder)	2.73	2.73

Analyst M. K. Carron, U. S. Geological Survey.

1. Red argillite from slope at altitude of 6,800 feet west of Willow Creek near center of sec. 32, T. 32 N., R. 42 E.

2. Red and green chert from same locality.

Comparison of analyses of the argillite and chert shows several interesting features. The argillite has a noteworthy content of silica (probably present largely as quartz fragments), and is correspondingly low in alumina, lime, and potash. The chert naturally has a higher silica content, but alumina, ferric oxide, magnesia, lime, and potash are lower in the argillite.

The problem of the origin of bedded cherts has been a subject of wide discussion, Davis (1918, p. 405) has studied cherts in the Franciscan group in California, and concluded that the silica was derived from contemporaneous volcanic activity. Taliaferro (1933, p. 54), Rubey (1929, p. 168), and Bramlette (1946, p. 55) have also emphasized the relationship of volcanic and pyroclastic rocks to cherts and siliceous shales.

Although volcanic rocks and pyroclastics are present in the Scott Canyon, Pumpernickel, and Valmy formation in Battle Mountain, none has been found in the Havallah formation. It thus appears that vulcanism does not always accompany bedded cherts, and the silica may have other origins. Time was not available to study the cherts in detail, but it seems likely that such a study would yield much data on the origin of bedded cherts.

INTRUSIVE ROCKS

The intrusive rocks of the Antler Peak quadrangle have been divided into two groups, major intrusive bodies and minor intrusive bodies. The major intrusive bodies are for the most part coarse grained to porphyritic in texture and range in composition from quartz monzonite to granodiorite; the minor intrusive bodies are related dikes and sills, but include more calcic rock types such as diorite and gabbro.

Major intrusive bodies

The major intrusive bodies of the area occur in four principal masses; on the northwest side of Copper Basin, in Trenton Canyon, in Elder Creek, and in Copper Canyon. They are for the most part of porphyritic habit, especially along the borders in Copper Basin and Copper Canyon the porphyritic habit persists throughout the intrusive. The central part of the intrusive in Trenton Canyon is equigranular, but the border facies is strongly porphyritic. In addition, many dikes, probably related in origin to the intrusive masses, occur in the area, chiefly on the eastern side of the range.

The composition of the major intrusive ranges from quartz monzonite to granodiorite, but more calcic varieties are also present as dikes and small intrusives. All these rocks are probably intruded during the same petrogenic cycle, but probably the diorite and the gabbro are earlier for they are more altered than the quartz monzonite and granodiorite.

Granodiorite in Trenton Canyon

The granodiorite in Trenton Canyon forms an irregularly shaped intrusive mass trending northwestward. The narrow part at the southeast is about 1,000 feet wide; it extends northwestward for about a mile and then widens abruptly to about 5,000 feet ending on the northwest side of the canyon about a mile away. The total length is a mile and a half. Dikes and sills related to the granodiorite cut the adjacent rocks, but are not nearly so abundant as the dikes in the eastern part of the quadrangle.

The granodiorite is for the most part porphyritic, but is medium-grained to coarse-grained with prominent phenocrysts of plagioclase and locally quartz. The central part of the mass is in places non-porphyritic.

The plagioclase generally occurs as complex crystals. The crystals commonly show zoning, grading outward from calcic into more sodic zones but locally showing oscillatory zoning in sections parallel to 010. Measurement of many crystals has shown rather uniform composition throughout the intrusive mass. The centers of the plagioclase crystals are as calcic as An_{42} and the thin outer border as sodic as An_{33}. In the central zones most crystals measure about An_{38-40} and therefore the average composition is well within the andesine range. The plagioclase clearly crystallized before the orthoclase and quartz. The orthoclase crystals are anhedral and include euhedral to subhedral plagioclase crystals.

The orthoclase crystals are generally in large plates, but orthoclase also cuts across the plagioclase crystals in irregular and veinlike masses. (See plate 32 B). Irregular perthitic intergrowths are present in some orthoclase crystals. Unlike the plagioclase, the crystals usually show strain shadows. On the whole the orthoclase is less altered than the plagioclase, indicating that the plagioclase was not in equilibrium with the late liquids that formed the orthoclase.

The quartz crystals are generally anhedral and formed interstitially with respect to the other crystals, but they also enclose earlier plagioclase, biotite, hornblende, and accessory minerals. The quartz also is in veins, and appears to replace the earlier crystals. In part, the quartz crystallized simultaneously with the orthoclase, for the two minerals are complexly intergrown and locally form micropegmatitic intergrowths.

The dark minerals are biotite and hornblende which make up 5 to 15 percent of the rock. The hornblende is in elongate crystals, generally subhedral. Most of the crystals are fresh, but some are partly altered to chlorite, epidote, and zoisite. To some extent the hornblende is intergrown with and replaced by biotite which in turn has been altered to chlorite. The hornblende is moderately pleochroic with X-light yellow green, Y-brownish green, and Z-clear green. $Z \wedge c = 22^{\circ}$. A few crystals are twinned.

The biotite is present in euhedral to subhedral plates. It is strongly pleochroic with X-light yellow brown, Z-dark brown. Some plates are irregularly replaced by pale-green chlorite, which shows slight pleochroism and "ultra blue" abnormal interference colors.

The biotite and hornblende are accompanied by sphene crystals, commonly euhedral wedges but also occuring as anhedral grains. Crystals 0.4 millimeter long are common, and some are as long as 0.75 millimeters.

The minor accessory minerals are apatite, a few crystals of zircon and magnetite partly altered to hematite. Rather indistinct radio-halos are present in the biotite, presumably surrounding crystals of zircon. The zircon present in the rest of the rock is in small, rounded grains.

Porphyry dikes.--Porphyry dikes associated with the intrusive body in Trenton Canyon are very similar to the parent rock. Specimens collected show phenocrysts of quartz, plagioclase, biotite, and hornblende. The plagioclase has a similar range in composition(An_{38-33}) to the plagioclase of the granodiorite and a similar crystal habit. The groundmass is a fine-grained intergrowth of orthoclase and quartz with a little plagioclase. (See plate 31.)

An unusual dike at the forks of Trenton Canyon cuts quartzite of the Havallah formation. The dike is light gray, fine grained, and contains small white phenocrysts. Under the microscope the rock is seen to be composed of a quartz-orthoclase intergrowth whose average grain size is 0.4 millimeters in diameter with some grains as large as 1.5 millimeters. Both the quartz and the orthoclase are anhedral, and the quartz commonly sends sharp projections into the orthoclase and between the grains. Sericite aggregates scattered throughout the rock are probably earlier remnants of plagioclase which has been entirely altered. Either the rock was intruded at a late stage in the magmatic cycle, or was altered by the liquids remaining at a late stage in the magmatic cycle.

Quartz monzonite in Copper Basin

The stock in Copper Basin is composed of quartz monzonite porphyry. (See plates 2, 17B). The principal mass is about a mile long and extends northwestward along the crest of the range, but apophyses, dikes, and sills underlie the western part of the basin and extend southward along the east side of the range as far as Little Cottonwood Canyon.

For the most part the porphyry is leached and altered by hydrothermal solutions, but in places fresh rock can be found. The fresh porphyry is medium gray, and has a fine-grained groundmass. Phenocrysts of quartz as much as 17 millimeters long, but averaging less than a 10 millimeters long are scattered erratically throughout the rock. Orthoclase phenocrysts are found in places; some are as much as 60 millimeters long. (See plate 15B) Plagioclase phenocrysts, commonly 3 to 5 millimeters long, which show indistinct twinning, make up possibly 20 percent of the rock. (See plate 28.) In addition biotite and hornblende are present in small crystals rarely more than a millimeter long.

In Iron Canyon several dikes which follow major fault zones were mapped. These dikes probably are related to the intrusive in Copper Canyon for they are only about 2 miles to the east, and are identical in appearance and mineral composition with dikes in the Copper Canyon area.

Weathered surface specimens of the dikes are generally light to medium gray, and have prominent phenocrysts of quartz and plagioclase as much as 10 millimeters long and averaging about 5 millimeters long. The groundmass is fine grained and contains minute crystals of biotite and hornblende and locally phenocrysts as much as a millimeter long.

In specimens taken from drill holes and underground workings where the rock has not been hydrothermally altered, the rocks are brownish gray, and the feldspar and quartz phenocrysts normally have a brownish cast.

Under the microscope thin sections of the porphyry show that the plagioclase is present in two generations, as phenocrysts and in the groundmass. The plagioclase phenocrysts, generally in complex crystals, are zoned with marked oscillatory extinction. The composition of the plagioclase ranges from An_{30} to An_{48}. Most of the crystals show sharp borders against the groundmass, but some have indistinct borders and have been partly replaced by orthoclase. (See plates 28, 31, and 32.) Generally the replacement is confined to the periphery of the plagioclase crystals, but irregular veinlets of orthoclase penetrate half the area of some of the plagioclase phenocrysts. Plagioclase is also found in the groundmass in small subhedral to euhedral crystals and laths surrounded by orthoclase.

The quartz is also present in two generations, in phenocrysts and in the groundmass. The phenocrysts are rounded and locally embayed by the groundmass; evidently they were attacked by the late liquids. Like the plagioclase, the quartz is peripherally replaced by the orthoclase, but to a lesser degree. The quartz in the groundmass is intergrown with the orthoclase and is present in places as micrographic intergrowths. The phenocrysts of biotite and hornblende scattered throughout the rock are on the whole fresh, but some of the hornblende crystals and a few of the biotite crystals have been altered to chlorite. The biotite is light in color and shows high birefringence colors almost like muscovite. Its pleochroism is marked X--very light yellow, Z-reddish brown. The hornblende is almost non-pleochroic, with X-colorless, Y-very light brownish green, and Z-colorless. Twinned crystals are common, and most crystals are euhedral. Inclusions of apatite and sphene are found in the larger phenocrysts. A little epidote and talc occur as alteration products in addition to chlorite.

The groundmass of the dikes is cloudy due to slight kaolinization, but it consists of orthoclase, plagioclase, and quartz whose relative abundance is in the order shown. The orthoclase is in anhedral crystals which include crystals of the quartz and plagioclase, and is intergrown with them. The plagioclase is present in laths and subhedral crystals and has the same general composition as the phenocrysts, although it is commonly not zoned. The quartz is in fine grains intergrown with orthoclase and in micrographic intergrowths.

Sanidine is a constituent of some dikes; it occurs in rare phenocrysts, and is altered to about the same extent as the plagioclase.

Granodiorite at Elder Creek

The granodiorite at Elder Creek comprises several more or less continuous intrusive bodies exposed on both sides of Elder Creek at the front of the range and in the foothills. The intrusive bodies are separated by alluvium and thin septae of sedimentary rocks, but may be connected at shallow depths and merely represent apical parts of a larger body.

The granodiorite (see plates 30 and 17A), is for the most part porphyritic in habit, and the groundmass ranges in grain size from very fine at the borders to medium coarse grained in the central parts. Generally the phenocrysts are larger and more prominent in the border facies; here the quartz and plagioclase grains are as much as 7.5 millimeters long. In the central parts of the bodies the phenocrysts rarely exceed 4 millimeters and they are set in a groundmass whose grains average about 2 millimeters in diameter.

A specimen collected at the range front on the east side of Elder Creek is a dark-gray rock containing phenocrysts of plagioclase, quartz, and biotite. The plagioclase shows a range from An_{45-31} and shows oscillatory twinning with the outer zones being more sodic. The plagioclase is partly altered to sericite, chiefly on the outer zones. The quartz phenocrysts are rounded, but some show bipyramidal form; the borders of the crystals are commonly sutured and projections extend a short distance into the groundmass. The biotite crystals are present in two generations, phenocrysts ranging from 2 to 4 millimeters in diameter, and fine-grained crystals occurring in aggregates and in the groundmass. The fine-grained aggregates are in part pseudomorphic after hornblende, and formed during the consolidation of the groundmass. Many of the biotite phenocrysts contain inclusions of zircon surrounded by faint radiohalos. Zircon is also present in small euhedral grains scattered throughout the groundmass and accompanied by apatite. Orthoclase occurs in sparse phenocrysts and in the groundmass intergrown with quartz. Some crystals in the groundmass show aggregate polarization and simultaneous extinction over an area as large as a millimeter in diameter.

Granite porphyry

A dike of granite porphyry in Little Cottonwood Canyon is representative of a group of more silicic dikes found in the quadrangle. The rock is light gray with small phenocrysts of feldspar and quartz generally less than a millimeter long; dark minerals are entirely lacking.

Under the microscope the rock is holocrystalline. Phenocrysts of plagioclase, quartz, and orthoclase are set in a groundmass of these minerals. The plagioclase phenocrysts are albite, about An_{10}, and are much more sodic than the andesine phenocrysts of most of the porphyry dikes.

A few orthoclase phenocrysts are present. Some plagioclase crystals have been partly replaced by orthoclase, leaving only pagioclase relics in the center of the crystals. The quartz phenocrysts show sutured borders and locally send projections into the groundmass.

The groundmass crystals range from .03 millimeter to .1 millimeter in diameter, and make up about 75 percent of the rock. Orthoclase and plagioclase predominate and quartz makes up about 25 percent of the groundmass. Muscovite is the accessory mineral; it occurs in irregular plates and fibers scattered throughout the groundmass. The orthoclase and plagioclase are relatively unaltered, showing only a slight turbidity.

Chemical composition

Although the igneous rocks in the area show a general similarity in mineralogy and composition, the relative proportions of the minerals is variable. Study of thin sections does not always give a clear idea of the chemical relations of the rocks. Accordingly, two samples of quartz monzonite from Copper Canyon and a sample of the granodiorite at Elder Creek were chemically analyzed for comparison. The analyses are as follows:

Analyses

Analyst, M. K. Carron, U. S. Geological Survey

	1	2	3
SiO_2	70.25	66.43	68.33
Al_2O_3	13.46	14.47	15.22
Fe_2O_3	3.42 1/	4.29 1/	.28
FeO	----	----	2.28
CaO	2.32	2.52	3.20
MgO	1.46	2.70	1.86
Na_2O	2.02	2.52	3.23
K_2O	4.88	4.22	2.92
H_2O −	.45	.30	.45
H_2O +	.90	1.12	1.46
CO_2	.08	.12	.34
TiO_2	.36	.42	.33
MnO	.02	.03	.06
BaO	None	None	None
P_2O_5	.15	.13	.10
S	.51	.81	.03
	100.28	100.08	100.09
Less O-S	.25	.40	.01
	100.03	99.68	100.08
Sp. gr (bulk)	2.66 2/	------	2.62 2/
Sp. gr (powder)	2.66	2.66	2.65

1/ Total Fe as Fe_2O_3; presence of considerable sulfur renders the determination of FeO impractical.

2/ Determined by Dr. Adolph Knopf.

Norms

	1	2	3
Quartz	31.98	24.99	31.50
Orthoclase	28.88	24.96	17.27
Albite	17.07	21.25	27.30
Anorthite	10.13	10.92	15.56
Corundum	1.13	2.29	1.47
Salic	89.19	84.41	93.10
Enstatite	3.65	6.74	4.65
Ferrosilite	1.65	4.20	2.77
Magnetite	1.39	.46	.46
Ilmenite	.67	.79	.61
Apatite	.31	.30	.24
Calcite	.18	.27	.08
Pyrite	.96	1.44	.06
Femic	8.81	14.20	8.87
Johannsen	(226"/7")	(226"/7")	(227")

1. Quartz monzonite from border facies of intrusive in Copper Canyon; 200 feet from portal of Farren adit, Copper Canyon mine. (See plate 28.)

2. Quartz monzonite porphyry from dike cut at 259 feet from collar of DDH No. 68. (See plate 29.)

3. Granodiorite from intrusive west of Elder Creek at range front. (See plate 30.)

The analyses show that the quartz monzonite of the intrusive in Copper Canyon (No. 1) and the related porphyry (No. 2) are similar in composition. The main intrusive is somewhat more silicic and slightly more potassic than the dike; the dike contains a higher percentage of alumina, lime and soda, but otherwise the difference is not striking. These differences were expectable from the study of the thin sections. The dike is probably a better sample of the original intrusive than the border facies, for the dike did not undergo the late stage silicification and introduction of orthoclase which characterized the main intrusive. The norm does not reflect accurately the composition of these rocks, for some of the potash calculated as orthoclase was probably derived from the biotite which is the principal dark mineral in both rocks. Moreover, part of the calcium which is present in the rocks as biotite and hornblende, is probably calculated as anorthite, thus making the percentage of anorthite higher than in the actual rock.

The granodiorite (No. 3) is intermediate in silica content between No. 1 and No. 2, but is higher in alumina and lime than both of them. In addition, No. 3 contains a higher percentage of soda than No. 1 and 2, and soda is greater than potash; this is reflected in the thin sections by predominance of plagioclase over orthoclase.

Quartz monzonites similar to Nos. 1 and 2 above have been described by Knopf (1918 a, p. 20-21) from the Yerington district, Nevada and the Inyo range (1918 b, p. 62-67). Hobbs (1948, p. 32-37) has described the granodiorite from the Osgood Range, Nevada. This granodiorite appears to be similar in mineralogy to No. 3 above, but is apparently somewhat more calcic.

Contact metamorphism

The contact metamorphism caused by the major intrusive bodies was not widespread, but was confined principally to an aureole a mile or less in diameter. As the intruded rocks were chiefly argillitic or arenaceous, they were metamorphozed to hornfels and quartzite. In some places calcareous rocks were cut by the intrusives and metamorphosed to hornfels and tactite.

The highest grade contact facies formed in the quadrangle belongs to the amphibolite facies (Turner, 1948, p. 76, 87) for they are composed of amphibole, garnet, plagioclase, and biotite. This facies formed along the intrusive contacts, and grades successively outward into epidote-amphibolite facies and then into greenschist facies.

In mineralized areas widespread bleaching of the intruded rocks has been noted. The bleaching is not strictly a metamorphic effect; it appears to have been caused largely by hydrothermal alteration that followed the contact metamorphism. In addition to the bleaching, the metamorphic minerals were altered, the feldspars to clay minerals and micas, and the amphiboles, garnets, and biotite to chlorite.

Metallization took place at three principal stages. The first stage accompanied the contact metamorphism; the second stage accompanied the hydrothermal alteration; a third stage followed the hydrothermal alteration.

Minor intrusive bodies

Gabbro, diorite, and quartz diorite

Small intrusive bodies of gabbro, diorite, and quartz diorite occur throughout the Antler Peak quadrangle. These intrusive bodies include stocks, dikes, and sills. At no place have dikes of these rocks been seen cutting other intrusive masses and their relative age is therefore unknown. Judging from the greater amount of alteration and deformation shown by them, they may be older than the quartz monzonite and granodiorite, but probably belong to the same general petrogene epoch.

Coarse-grained gabbro dikes were mapped in Trenton Canyon and in the adit north of the Carissa mine in Copper Basin. These rocks are characteristically darker in color than the diorite dikes, because of a higher content of mafic minerals. The relationship of the gabbro dikes to the diorite and porphyry dikes is not known, but it is likely that the gabbro dikes were also intruded early in the intrusive cycle.

The gabbro from Trenton Canyon is coarse-grained with blades of dark-green hornblende as much as 3 millimeters long separated by white plagioclase laths. Under the microscope the plagioclase and hornblende are intergrown in a subophitic texture. The plagioclase is labradorite about An_{50-55} in composition; it is turbid because of alteration to clay minerals. The hornblende is slightly pleochroic with X-very pale brown, Y-light brown, and Z-light brownish green. $Z c -17^{\circ}$. The hornblende is partly altered to chlorite and fibrous actinolite. An opaque mineral probably ilmenite, has been altered to a white material which resembles leucoxene. Small reddish-brown specks scattered throughout the leucoxene are probably hematite.

The gabbro from Copper Basin is similar to the gabbro from Trenton Canyon in mineral composition and texture, but is more highly altered. The plagioclase is zoned and shows a range in composition from An_{58} to An_{45}. The hornblende is moderately pleochroic with X-very pale brown, Y-light brownish green, Z-clear green. The alteration products of the hornblende are fibrous actinolite, chlorite, calcite , and a little zoisite. Biotite is an accessory mineral; it occurs in minute plates and small fibers replacing hornblende.

A gabbro dike from Timber Canyon is of interest for it shows, in addition to hornblende, **augite** as a mafic mineral. The plagioclase of this rock shows a range from An_{50-60}. The plagioclase is intergrown with augite and hornblende. The augite is for the most part in granular aggregates which are interstitial to the plagioclase; some of the aggregates show crystal boundaries, but generally they are anhedral. In part, the hornblende appears to be contemporaneous with the augite, but most of it is probably later. The hornblende occurs intergrown with the augite and in fibrous aggregates. The pleochrism is slight, more like actinolite than hornblende, with X-light brown, Y-colorless, and Z-very light green. A prominent accessory mineral in the rock is sphene which occurs in large crystals and crystal aggregates with the augite and hornblende. The iron ores are lacking in the rock.

A diorite dike in Little Cottonwood Canyon is a fine-grained dark greenish gray rock cutting the Scott Canyon formation. Plagioclase, the predominant mineral, is An_{50-42} and occurs in subhedral laths partly replaced by sericite and muscovite. The mafic minerals are almost entirely altered and replaced by serpentine, calcite, chlorite, and fine-grained clay minerals. Interstitial quartz is present throughout the rock, and makes up about 3 percent of the volume; most of the quartz fills spaces between the plagioclase crystals, but part of it replaces the feldspar and other minerals. Biotite is a secondary mineral which has been only partly altered. It forms plates and bundles of fibers usually associated with skeletal crystals of ilmenite or titaniferous magnetite. Apatite is present as an accessory mineral.

One small intrusive mass of quartz diorite is exposed in the saddle east of the pass at the head of Copper Canyon. Here the diorite cuts sandstone of the Harmony formation and the overlying Battle formation. The diorite is a fine-grained, medium-gray rock with indistinct plagioclase phenocrysts along the borders of the intrusive.

Under the microscope the quartz diorite is seen to be composed of plagioclase and augite, now altered to chlorite and serpentine, and quartz. The plagioclase is present in subhedral laths which are partly sericitized and replaced by calcite but which on the whole are fresh. Measurements of several grains gives a composition of An_{45}. The augite is almost entirely altered to chlorite, calcite, and serpentine, and its optical properties cannot be determined. The quartz is interstitial and is present in anhedral grains and micrographic intergrowths with the plagioclase. In a few places orthoclase accompanies the quartz and was evidently formed at the same time. The calcite which replaces the feldspars and the augite is locally accompanied by epidote.

Pebble dikes

One of the interesting geologic features of the area is the occurrence of pebble dikes in Copper Basin. Pebble dikes have been described from many localities in the western states, and their origin has been the subject of wide disagreement. (Farmin, 1935).

The pebble dikes of Copper Basin that have been studied are in the Contention mine and in an adit about 750 feet to the south. (Sec. 29, T. 32, N., R. 44 E.) The dikes cut silicified sandstone of the Harmony formation; they appear to be breccia zones at first glance, and have been so mapped, but they contain rock types not present in nearby exposures. Pebble dikes in both places contain fragments of the Scott Canyon formation; namely, chert, argillite, and greenstone which could have come only from depth. The depth of origin of the material is conjectural, but the deepest workings and drill holes in the district have not crossed the Dewitt thrust fault which forms the basal contact of the Harmony formation. It is probable that the fragments of Scott Canyon formation have traveled upward at least 500 feet and the distance may be as much as 1,000 feet.

The pebble dikes consist of fragments of dike porphyry, sandstone and hornfels of the Harmony formation and chert, argillite, and greenstone of the Scott Canyon formation. These fragments are in a matrix in crushed rock which is soft and friable, and appears to be uncrystallized although crushed and broken. The fragments are commonly less than an inch in diameter, but locally fragments up to 8 inches in diameter occur. Generally the fragments are subangular, but the corners have been rounded, and some fragments are well rounded.

Under the microscope the rock is a breccia. The large fragments have rounded edges, but they are set in a crushed matrix of particles ranging from 0.001 to 1 millimeter in diameter.

The fragments of porphyry in the pebble dike are not highly altered. Some are cut by partly sericitized quartz veins, but these veins were formed before the porphyry was incorporated in the dike, and the sericite was also developed earlier. Likewise the fragments of phyllite, argillite, and chert are not altered. Generally they are surrounded by a thin envelope or film of black finely crushed material, probably carbonaceous argillite or phyllite.

The groundmass is made up of comminuted mica, carbonaceous material, quartz, clay minerals, and rock fragments. The orientation of the fragments is random and there is no evidence of flowage. Cubic crystals of pyrite are scattered through the rock and were probably formed after emplacement.

Age of the intrusive rocks

The age of the intrusive rocks in central Nevada has been one of the major problems in Nevada geology. In most places direct evidence of the age is lacking; the intrusives generally cut Paleozoic and early Mesozoic rocks, and are unconformably overlain by Tertiary rocks.

Ferguson (1929, p. 130), and Nolan (1943, pp. 162-163), have discussed the literature regarding the age of the intrusive rocks in western Nevada. They have concluded that some intrusives are of late Jurassic age, but that there is no direct evidence as to the age of most of them. The nearest intrusive rocks which are reasonably well dated are in California and Idaho. Hinds (1934, p. 191), has shown that in the Klamath mountains and in the northern part of the Sierra Nevada the batholith is probably late Jurassic. Ross (1935, p. 15), considers that the Idaho batholith was intruded at or soon after the end of the Jurassic.

Preliminary studies in the Sonoma Range quadrangle have shown that two distinct kinds of intrusives are present in the quadrangle. One is composed of a single rock facies of quartz monzonitic or granodioritic composition, commonly porphyritic along the borders and holocrystalline in the central part. The intrusives of the Antler Peak quadrangle belong to this kind. The other kind is composed of rocks ranging from gabbro to alaskite with 3 to 5 easily recognizable intermediate rock types. The intrusive mass in the Buffalo Range 10 miles to the northwest belongs to this kind. Although both may be related, they were probably intruded at different times and under different conditions. The evidence is not conclusive, but it is thought that the intrusives composed of a single rock facies are younger than the complex intrusives.

In the Antler Peak quadrangle the youngest rock cut by the intrusives is Permian, but similar intrusives south of the Buffalo Range (to the west) cut Triassic rocks. The intrusive rocks cut the Golconda thrust, which is thought to be Jurassic. (Ferguson, Roberts, and Muller). The intrusive rocks thus may have been intruded during late Jurassic, but it is also possible that the intrusives may be of Cretaceous age.

TERTIARY ROCKS

Rocks of Tertiary age formerly covered much of north-central Nevada, but they have largely been removed by erosion. Remnants of these rocks that crop out in the Antler Peak quadrangle include flows of rhyolite and associated pyroclastic rocks, basalt flows, and gravels. These rocks have been grouped in three units on the geologic map. (See plate 2.)

Rhyolite

Rhyolite flows occur as isolated remnants of formerly much more extensive plateau lavas in the southwestern part of the quadrangle in Rocky Canyon, in the eastern part of the quadrangle at Copper Basin, and in the northwestern part of the quadrangle at the Oyarbide ranch.

In the Fish Creek Mountains south of the Antler Peak quadrangle much of the upland area is underlain by rhyolitic volcanic rocks and associated pyroclastics. North of Battle Mountain, Shoshone Mesa is the southern extension of broad lava fields that cover southern Idaho and southwestern Oregon. It is likely that the Battle Mountain area was largely covered with rhyolitic volcanic rocks during the mid-Tertiary, and subsequent erosion has left only the isolated remnants which have been mapped.

Rhyolites from the Fish Creek Mountains south of the Battle Mountains were described by Zirkel (1876, VI, p. 189), as being extremely rich in phenocrysts. The quartz phenocrysts are dark, smoky like topaz because of films of iron oxide on cracks in the quartz. The feldspars are sanidine and plagioclase in a microfelsitic or crystalline-granular groundmass.

The following analyses are quoted from Zirkel:

SiO_2	75.44	75.55
Al_2O_3	13.98	13.67
Fe_2O_3	0.54	0.56
CaO	0.50	0.50
MgO	trace	trace
Na_2O	3.48	3.50
K_2O	5.36	5.29
H_2O	0.77	0.85
	100.07	99.93

R. W. Woodward, analyst. (Hague and Emmons, vol. 2, p. 664.) The rhyolite is noteworthy because of the low content of calcium, iron, and magnesium. This together with the high content of potassium would indicate that the biotite content of the sample was low or entirely lacking, and that the rock was essentially an aggregate of sanidine, plagioclase, and quartz with a little iron oxide. Hague (1899, 2, p. 671), considered the rhyolite in the Battle Mountains as "the same normal type which characterizes the Fish Creek and Augusta Mountains." Specimens collected by the writer in all these areas show similarity in color, texture, and structure.

The rhyolites of Battle Mountain rest on a surface of low to moderate relief, but subsequent block faulting has so tilted and warped this surface that little is known concerning its original slope. At the head of Rocky Canyon the base of the rhyolite is at an altitude of about 7,000 feet, and in the head of Cottonwood Canyon a rhyolite remnant is at an altitude of about 7,200 feet. The rhyolite has been eroded from the intervening area, and although it may not have covered the highest peaks, it is likely that much of the southwestern and northwestern part of the quadrangle was covered, for pyroclastic rocks are exposed in the blocks down-faulted along the western side of the range near the Buffalo Valley mine. Beginning at the range front a mile north of Trenton Canyon, rhyolite and underlying pyroclastics are exposed at an altitude of about 6,000 feet in a narrow belt extending to the Oyarbide ranch. This belt was preserved from erosion during the late Tertiary and Quaternary by downfaulting.

Rhyolite which forms the small cap on the ridge between Copper Canyon and Willow Creek is a light-gray rock with small phenocrysts of quartz in a banded groundmass showing prominent flow structure. This remnant indicates that formerly much more of the southern part of the range was covered by the flows.

Under the microscope (pl. 33A), the rhyolite is composed largely of glass, whose index is 1.51, in which phenocrysts of quartz, sanidine, oligoclase-andesine, and biotite are found. (See plate 33 B). The phenocrysts range from 0.5 to 1 millimeter in length. The quartz phenocrysts are subrounded for the most part, but some are euhedral and show pyramidal faces. The quartz is fractured and some of the fractures are filled with glass. The sanidine phenocrysts are subhedral and most of them are fractured. The plagioclase is oligoclase and sodic andesine ranging from An_{35} to An_{28}; generally the crystals are anhedral. The glassy groundmass shows flow struture which is accentuated by differences in composition of the glass. In some layers the glass is clear except for a few tiny microlites, but in other layers the glass is turbid because of abundant microlites and is brownish in color. The clear glass generally has perlitic structure and locally has pumiceous structure. The biotite is present in laths, many of which show bending because of the flowage. The biotite is strongly pleochroic with X-medium yellow brown and Z-dark brown to black. Magnetite, zircon, and apatite are the accessory minerals.

Fragments of argillite from the underlying Pumpernickel formation are locally included in the rhyolite. They are not noticeably altered, except that the mica content seems higher than normal. The mica may have been formed earlier, during the folding of the rocks.

Rhyolite forming the flow remnant in the head of the south fork of Cottonwood Canyon is medium reddish gray, and contains small phenocrysts of quartz, feldspar, and biotite.

Under the microscope it is seen that the feldspar phenocrysts are plagioclase and sanidine, and that the groundmass is composed of turbid glass and spherulites. The plagioclase is oligoclase ranging from An_{29} to An_{25}. The biotite phenocrysts contain abundant inclusions of iron oxide, probably both hematite and magnetite, and many biotite crystals have peripheral coatings of the iron oxides. The spherulites of the groundmass range from small specks showing aggregate polarization to spherules 0.5 millimeters across. The index of the spherulites is less than balsam and they are probably composed of potash feldspar and crystobalite. Commonly the spherulites show a concentric as well as a radial structure. In parts of the rock which show flow structure the spherulites are alined with this structure and began to form before flowage had ceased. An unusual accessory mineral found in the rhyolite is tourmaline. Only a single grain was found, and its presence may be accidental, possibly from sands over which the rhyolite flowed.

Rhyolite from exposures on the west side of Willow Creek is grayish to reddish brown, and contains prominent phenocrysts of quartz, feldspar, and biotite. Plagioclase feldspar whose composition is An_{30-38} is abundant in the rock; the plagioclase seems abnormally calcic, but it is probable that most of the calcium in the rock is in the plagioclase which crystallized early. The sanidine commonly shows Carlsbad twinning. The groundmass is glass, but in places lines of spherulites have formed. Flow structure is well shown by the spherulites and microlites.

The rhyolite east of Copper Basin caps the prominent peak named Elephant Head and forms the foothills which extend two miles to the east. Similar rhyolite crops out just south of the southern border of the quadrangle and east of the quadrangle, and it is possible that another belt has been downfaulted and is now covered with alluvium within the boundaries of the quadrangle.

The age of the rhyolite is not definitely known, but it is similar in lithology and stratigraphic relations to rhyolite between Battle Mountain and Elko, Nevada which is considered Miocene. (Sharp, 1939.)

Basalt

Basalt flows cap the ridge southeast of Copper Canyon, the point south of Rocky Canyon, and three erosional remnants are exposed near Cottonwood Creek south of the Marigold mine. The basalt flows southeast of Copper Canyon extend south of the quadrangle and cap several hills underlain by rhyolite flows and pyroclastics.

The basalt flows are peripheral to the range, and were extruded after the uplift of the range had begun, but probably before it had reached its present altitude. The flows in Philadelphia Canyon reach an altitude of 5,850 feet, and stand about a thousand feet above basalt flows capping rhyolite just south of the quadrangle. This probably gives a rough measure of the amount of uplift of the range since the extrusion of the basalt. On the northside of Philadelphia Canyon, washed stream gravels beneath the basalt are as much as 20 feet thick. The gravels are well bedded, but poorly sorted and were evidently laid down by streams of high gradient. In places these gravels are auriferous and some channels in them have been mined.

The basalts form massive flows with poorly developed columnar jointing in most places. The basalt parts of the flows are vesicular and scoriaceous, and are generally colored red by alteration. The upper parts of the flows are also commonly vesicular.

Basalt from the lava cap on the ridge south of Rocky Canyon is black and aphanitic with plagioclase phenocrysts as much as 3 millimeters long. Under the microscope the basalt is seen to consist largely of plagioclase, olivine, augite, and iron oxides. The plagioclase is present in phenocrysts and laths in the groundmass ranging from .05 to 0.35 millimeters. The large phenocrysts contain abundant microlites of augite grains and of magnetite. The microlites are also present in the groundmass, but here they are not included in the plagioclase crystals but are intergrown with them. Borders of some phenocrysts are also free of microlites, and it is clear that the crystallization of the augite was contemporaneous with most of the plagioclase, but that the augite had completed crystallization before the last plagioclase liquid crystallized. Measurement of the zoning in the plagioclase shows a range from about An_{70} to An_{50} in most crystals. One crystal that was measured showed reverse zoning with a core of An_{42}, a middle ring of An_{60}, and an outer ring of An_{72}. This crystal is unusual and does not necessarily indicate the course of crystallization of the plagioclase in the flow. The middle zone of An_{60} contained augite crystallites, and the core and outer zone were free of microlites. The olivine is in light greenish yellow crystals as much as millimeter long. Most of the crystals are fresh, but some ~~partly altered~~ to a reddish-brown alteration product, probably iddingiste.

Most of the crystals are anhedral, but a few are subhedral. Magnetite is scattered throughout the rock, and some hematite accompanies the magnetite. In addition to the augite in the microlites, a few augite crystals are scattered throughout the rock. The augite is colorless and is in crystals generally less than 0.4 millimeter long. The crystals seen did not permit accurate measurement of the optical properties.

The age of the basalt is not definitely known. Because it was extruded after the uplift of the range had begun but before the range had reached its present altitude, the basalt is thought to be late Pliocene but may be early Pleistocene in age.

Bench gravels

Gravels of late Tertiary or early Quaternary age are preserved in three areas in Battle Mountain. One area is southwest of Antler Peak on the ridge above Willow Creek, (7,196 feet altitude); another is on the high ridge north of Trenton Canyon (7,950 feet altitude). The other is much lower, just north of the Buffalo Valley mine (5,750 feet altitude) on low hills rising above the fan.

The gravel remnants are composed of coarse gravels containing boulders of conglomerate, quartzite, rhyolite, and limestone. Single boulders are as much as 30 inches in diameter and many are more than 18 inches. The boulders are for the most part subrounded, but some are well rounded. The limestone boulders are naturally more abundant in the remnant near Antler Peak; only a few remain in the remnant north of Trenton Canyon, and limestone is absent in the gravel near the Buffalo Valley mine.

The gravels were deposited by streams flowing from the crest of the range westward. The streams were competent to carry large boulders and therefore had high gradients. The gravels were probably deposited before the range was uplifted to its present elevation, and before the canyons were deeply incised. The gravels are probably not contemporaneous, but were deposited at different stages during the uplift of the range. They are clearly younger than the rhyolite flows, but may be in part contemporaneous with the basalt flows.

Some of the gravel remnants (Qoa) near Cottonwood and Trout Creeks at the range front may be correlative with these bench gravels, but until further detailed work is done, no specific correlations will be made.

QUATERNARY ROCKS

Sedimentary rocks of Quaternary age flank Battle Mountain on all sides, and cover nearly a third of the Antler Peak quadrangle. The Quaternary rocks have been subdivided into three units, the older alluvium (Qoa), the younger alluvium (Qya), and flood plain silts (Qs).

Quaternary alluvium

The gravels which make up the fans that surround the range and occur in the stream valleys and terraces in the range were probably deposited over a long period of time, but for convenience they will be divided into two principal units, the older gravels (Qoa), and younger gravels (Qya).

Older alluvium.--The older alluvium (Qoa) includes the fans around the range which were deposited during the canyon cycle when the present range was sculptured. The canyons were incised deeply into the mature upland, and coarse detritus was deposited in the basins and valleys around the range. The fans were built up gradually by intermittent streams and by flash floods which occurred from time to time. There was some reworking of the alluvium as it was deposited by streams swinging across the fans, but the material is poorly sorted for the most part, and the bedding is generally indistinct. Near the range front the fans contain boulders up to 5 feet in diameter in a matrix of material ranging from cobbles to silt side. The most characteristic features of the fan deposits are the lack of sorting and angularity of the fragments. In addition, the boulders are composed largely of rock types derived from nearby sources. The age of the older alluvium is believed to be Pleistocene for it is post-basalt (Pliocene?) and pre-Lahontan (Wisconsin).

The alluvial fans extend outward from the range, sloping steeply near the range and grading imperceptibly into the valley floors. On the west and south side of the range the fans between the altitudes of 5,500 feet and 6,000 feet have gradients as steep as 500 feet to the mile and are locally steeper. Between 5,250 feet and 5,500 feet the gradient averages about 300 feet to the mile, but below 5,250 feet it is about 200 feet to the mile and continues to drop markedly into Buffalo Valley until it is only about 30 feet to the mile at the former high shoreline of Buffalo Lake (4,640 feet).

The fans have been deeply incised near the range front. In Trenton Canyon the depth of the incision is nearly a hundred feet and steep-walled chasm extends headward for about a mile then opens into a broad valley in the interior upland. Mill Canyon and Timber Canyon also show comparable incisions, but not as deep as Trenton Canyon. Cottonwood and Trout Creeks, which drain to the Humboldt River, flow in deep gorges within the range, but are not incised so deeply in the fans at the range front.

At the Buffalo Valley mine the fans are cut by a major fault. The fault is well exposed in the mine workings, and dips about 50° W., dropping fan gravels down in contact with rocks of the Havallah formation. Other parallel faults occur between the mine and the range front, and others which had gravel on both the downthrown and upthrown sides were mapped north of the mine.

The alluvial fans on the northeast and southeast sides of the range have lower gradients than those on the west side of the range. Near the range fronts the fans have gradients as much as 400 feet to the mile, but generally the gradient is 300 feet to the mile or less above an altitude of 5,000 feet. Below 5,000 feet in altitude the gradients drop gradually to 100 feet then to 50 feet to the mile as the Humboldt and Reese River flood plains are reached.

Incision of the fans on the northeast and southeast sides of the range is not as marked as on the west and south sides, but is noticeable in Galena, Little Cottonwood, Long Canyon and Elder Canyon. The depth of the incision is commonly less than 20 feet at the range front, gradually decreasing outward from the range. No conspicuous faults were noted on the fans on these sides of the range, but alinement of heavy sage brush growth about a mile east of the range front at Little Cottonwood Canyon may mark a minor fault trending north.

At the range front a mile northwest of the mouth of Elder Canyon the upper part of the fan is dissected and bedrock is exposed. The exposures extend about a half mile down the slope where they are gradually covered by gravels, first in the interstream areas, then in the stream channels. The upper part of the fan slope is actually a pediment, here cut on the relatively unresistant rocks of the Harmony formation. Elsewhere, near the mouth of Elder Creek, and south of Long Canyon, small pediments were formed at the heads of the fans. Possibly prior to the last stage of fan formation pedimentation was more extensive, but the fan gravels now cover the critical areas and little is known of the surfaces on which the fans were deposited.

<u>Younger alluvium.</u>--At some time prior to the last major uplift of the range when the fans had reached their maximum development, climatic changes, possibly related to pre-Wisconsin glacial stages, caused the streams to cut down. The upper parts of the fans and the fill in the

headwaters of the valleys within the ranges were incised as much as a hundred feet. The materials of the fans and the fills were reworked and redeposited on the floors of the valleys. The deposits of the later period are called the younger alluvium (Qya). In some places as in the headwaters of valleys and upper parts of the fans, the younger and older alluvium could not be definitely separated. The contacts between them in such places were therefore arbitrarily located.

The lithology of the younger alluvium differs little from the older alluvium, except that the gravels of the younger alluvium are better rounded and sorted and are confined to the stream courses and narrow channels in the upper parts of the fans, and spread out on the lower parts of the fans. The younger alluvium is for the most part thin, and is generally only a few feet thick on the lower parts of the fans. The younger alluvium is probably Recent in age for it is incised in the older alluvium of Pleistocene age and is still being deposited.

Flood plain deposits

The valley of the Reese River crosses the southeastern part of the quadrangle and that of the Humboldt River crosses the northeastern part of the quadrangle. At the base of the alluvial fans which flank the range, the fine-grained fan deposits interfinger with river silts deposited during flood periods. As the streams meander in their flood plains they have eroded the toes of the fans by lateral cutting, and deposited fine-grained materials. These deposits have been differentiated on the geologic map as flood plain silts (Qsa). In addition to the silts deposited by the rivers, the areas contain some windblown silt and fine sand which have piled up in low hummocks and small dunes.

The flood plain deposits are generally alkaline and many areas have alkali crusts formed by evaporation of salts brought to the surface by ground water. Because of the presence of alkali, these deposits are white or light gray in most areas, but locally they are light brown or buff. Excavations in these deposits show intercalations of sand and fine gravels which were probably brought down during periods of floods in the mountains. Since they form the flood plains of the present rivers they are also of Recent age.

STRUCTURE

The structural history of Battle Mountain and the surrounding region is extremely complicated. We now know that three orogenic movements, two in the later Paleozoic, and one in the Mesozoic, have affected the rocks of the area. During each of these orogenies the rocks have been complexly folded and thrust faulted with varying degrees of intensity throughout the region.

The working out of the structural relations of the rocks in the Antler Peak quadrangle has played a major role in unravelling the structural problems of the Sonoma Range quadrangle. The Paleozoic orogeny was first noted in Edna Mountain, but could not be closely dated from the exposures there. It was only after detailed mapping in the Antler Peak quadrangle that their full significance was realized. This led to a reappraisal of structural data in other parts of the Sonoma Range quadrangle, and a clearer understanding of the relationships between folds and thrust faults of the different orogenic epochs.

Paleozoic history of north-central Nevada

The oldest rocks in north-central Nevada are Cambrian quartzites, phyllites, and limestones exposed in Edna Mountain, Sonoma Range, and Osgood Mountain. Ordovician phyllites, cherts, and quartzites overlie the Cambrian rocks conformably. No strata of Silurian or Devonian age are known in the area.

In Edna Mountain, the Cambrian and Ordovician rocks are tightly folded and locally overturned, and overlain with marked angular unconformity by Pennsylvanian and Permian rocks. Not only was the Mississippian removed, but also a considerable part of the Cambrian and

Ordovician, and whatever strata of Silurian and Devonian age might have been present. In Battle Mountain this structural break is also present and is even more significant; here rocks assigned to the Mississippian were folded, thrust faulted, and beveled by erosion. Then in the lower Pennsylvanian coarse clastics (Battle formation) derived from a rugged landmass were deposited on the beveled strata by streams.

Marine conditions again prevailed during the deposition of the upper beds of the Battle formation and the Antler Peak limestone. Uplift and local erosion continued at intervals during the Permian, and disconformities at the base of the Edna Mountain formation may well indicate more serious disturbances elsewhere in the region.

The Paleozoic rocks of Battle Mountain were subjected to two orogenies during the late Paleozoic. The first, and apparently stronger pulse took place probably in the late Mississippian and early Pennsylvanian; it is named the Antler orogeny. Thus far it has been recognized only in the lower plate facies of the Golconda thrust fault. The second orogeny affected both the rocks of the lower plate and upper plate, but was stronger in the upper plate; this orogeny took place in the Permian.

Antler orogeny

The name Antler orogeny is here given to the orogenic disturbance which took place prior to the deposition of the Battle formation, probably during the late Mississippian and early Pennsylvanian. It is named for Antler Peak on whose slopes it is so well shown, but is recognizable throughout Battle Mountain, Edna Mountain, Sonoma Range, Osgood Range, and Shoshone Range.

The orogeny was first recognized by the writer in 1942, but its significance was not fully realized until August 1946, when Mr. Ferguson and the writer traced the unconformity at the base of the Battle formation through the central part of Battle Mountain and demonstrated that it rested successively upon the Harmony, Scott Canyon, and Valmy formations, and overlapped thrust faults of Paleozoic age. Later in 1946 and in 1947 the orogeny was recognized in the other ranges of north-central Nevada, and the conviction grew that it is a structural feature of regional importance.

The most striking feature of the Antler orogeny in the Dewitt thrust fault which separates the Scott Canyon formation on its lower plate from the overriding Harmony formation on the upper plate. The rocks in both plates of the thrust are complexly folded, and thrust faults are mapped within the lower plate. (See plate 2.)

Dewitt thrust.--The Dewitt thrust is one of the most important tectonic features of the Antler Peak quadrangle because it formed the plane of movement on which the Harmony formation was carried over the Scott Canyon and Valmy formations. The Dewitt thrust is younger than the thrust on North Peak for a klippe of the Harmony formation rests on the upper plate of the North Peak thrust about half a mile east of North Peak.

The Dewitt thrust has been traced from the range front in sec. 26, T. 33 N., R. 43 E. southward 5 miles to the Dewitt mill. Throughout this part of its course the thrust appears to dip 20° -50° E. (See plate 2, sec. A-A'.) Near the mill the thrust is offset by normal faults and repeated. A parallel segment of the thrust a mile west of the Dewitt mill dips steeply westward, presumably because of tilting on the later normal faults. (See plate 2, sec. B-B'.) From this point the trace of the thrust continues southwestward to the valley of Cottonwood Creek where it is cut off by a normal fault that is overlapped by the Battle formation. There are no actual exposures which show the Battle conglomerate resting on the trace of the Dewitt thrust, but the geologic map (plate 2), clearly shows that the Battle formation rests successively on the Harmony, Scott Canyon, and Valmy formations as it extends northwestward across the central part of the range.

The Dewitt thrust has been folded and brought to the surface again in the eastern and southeastern part of the quadrangle. (See plate 2, sec. C-C'.) The trace of the thrust extends southward from the Buckingham mine in a sinuous outcrop, broken and repeated by many normal faults. The underlying Scott Canyon formation is exposed in Little Cottonwood Canyon as far westward as the end of the road. Here a set of normal faults which extend southward to Philadelphia Canyon have dropped the upper plate of the thrust down on the west side. On the ridge between Little Cottonwood and Galena Canyon segments of the thrust (see section C-C'), have been displaced on a group of steep faults; the thrust has been warped forming a south-pitching anticline in this area. South of Galena Canyon the thrust has been eroded except for two klippen between Iron Canyon and Philadelphia Canyon. West of Philadelphia Canyon and west of the normal faults separating the Harmony formation and the Scott Canyon formation the Dewitt thrust has been buried at depth. The dip of the Dewitt thrust is gently undulating throughout most of the southeastern part of the quadrangle, but locally along faults the dip is steeper because of drag or tilting.

The dip of the thrust in the headwaters of Little Cottonwood is southeastward, possibly caused by tilting on normal faults which have repeated the thrust. Near the Buckingham mine the thrust dips northward at a low angle, and is cut off by a normal fault just east of the mine.

Folds above the Dewitt thrust.--The structure of the upper plate of the Dewitt thrust is not well known. Many strikes and dips have been measured, and in places the general structure is clear, but because the Harmony formation weathers to smooth slopes in most places with rather sparse outcrops, this could not be done everywhere. In addition there are no key horizons that can be followed any great distance for individual beds are highly lenticular.

One of the areas where the structure is well exposed is in the headwaters of Little Cottonwood Canyon, and in adjoining Cow Canyon. On the ridge between the canyons about a mile east of Antler Peak, the major structure is a syncline, overturned to the east, whose axis is shown on plate 2 (sec. C-C' and plates 10, 11A). The core of the syncline is marked by a folded diabase sill whose eastern limb dips westward about 40°, and whose western limb is vertical or overturned to the east. Minor warps and folds are superimposed on this major fold; the minor folds generally strike parallel to the major fold, and pitch gently north.

Elsewhere the structure in the Harmony formation of the upper plate is not clear. Many small folds have been mapped, but few can be traced for more than a few hundred feet. In general most of the folds are tight and trend northward. Locally, one of the limbs is overturned, and the overturn is to the east. (See plate 13-B). Although the folding may be older than the thrust faulting, it seems likely that the folding and overturning must be related in part at least to the thrusting. The overturning to the east shown by the major folds as well as the minor folds probably is supporting evidence that the upper plate came from the west. (See page 9.)

Folds below Dewitt thrust.-- Little is known of the folds in the Scott Canyon and Valmy formations below the Dewitt fault. In the North Peak area, the major folds are broken by both thrust and normal faults. Near the mouth of Cottonwood Creek the strata appear to be folded into tight folds striking northward. On the north side of North Peak, quartzite beds of the Valmy formation dip to the north; lack of bedding in the quartzite and crumpling of the interbedded cherts and shales make determination of the structure difficult, but the major structure appears to be a series of broad folds pitching northward.

Thrust faults below the Dewitt thrust.--Two thrust faults cut the Valmy and Scott Canyon formations below the Dewitt thrust south of the North Fork. (See plate 2, sec. A-A'.) Both thrusts strike northeastward and dip southeastward at angles ranging from 30° to 40°. They appear to be related and may be imbrications of a single thrust. The two thrusts (see sec. A-A'), separate a belt of the Scott Canyon formation from the Valmy formation on the lower plate of the lower thrust and the upper plate of the upper thrust. To the south the lower thrust is overlapped by the Battle formation, and the upper thrust ends against a normal fault. On the north the two thrusts join just before they reach the North Fork, and their extension is cut off by a normal fault trending northwest.

Although many strikes and dips were taken on the ridges north and south of Trout Creek, the structures beneath the thrusts are not definitely known because the beds are poorly exposed. Probably the rocks were folded prior to thrusting, and in places the thrusting may have steepened and overturned the beds to the westward. The shaly and cherty strata of the Scott Canyon formation between the thrusts are highly crumpled, and few strikes and dips were taken there. The Valmy formation of the upper plate of the upper thrust appears to be complexly folded, but whether the folds were formed prior to thrusting or during thrusting could not be determined.

North of the North Fork valley the contact between the Valmy formation and the Scott Canyon formation appears to be a thrust fault. This is a different thrust from the one just described which ends in the valley of the North Fork, for they dip in opposite directions and are structurally quite different. To avoid confusion, the thrust fault on North Peak will be called the North Peak thrust. On the north slope of the peak it is not well exposed, but on the south slope it appears to strike northwest and dip southwest. It flattens near North Peak, then changes strike to the westward and dips to the northeastward on the north slope of the range. On the north slope of the range it is clearly a thrust fault which cuts across structure in both the upper and lower plates, and separates the quartzites and cherts of the Valmy formation from the black argillite and cherts of the Scott Canyon formation. Many normal faults of small displacement cut the thrust, but do not displace it more than a few hundred feet.

Normal faults.—Normal faults probably formed during the Paleozoic but few were seen that could be definitely dated. Generally the normal faults definitely assignable to the Paleozoic are minor breaks which displace beds but end against Paleozoic thrust faults. Probably many normal faults were initiated in the Paleozoic, and underwent repeated movement during later cycles of faulting. As no Paleozoic normal faults of major importance were recognized they are not differentiated on the geologic map.

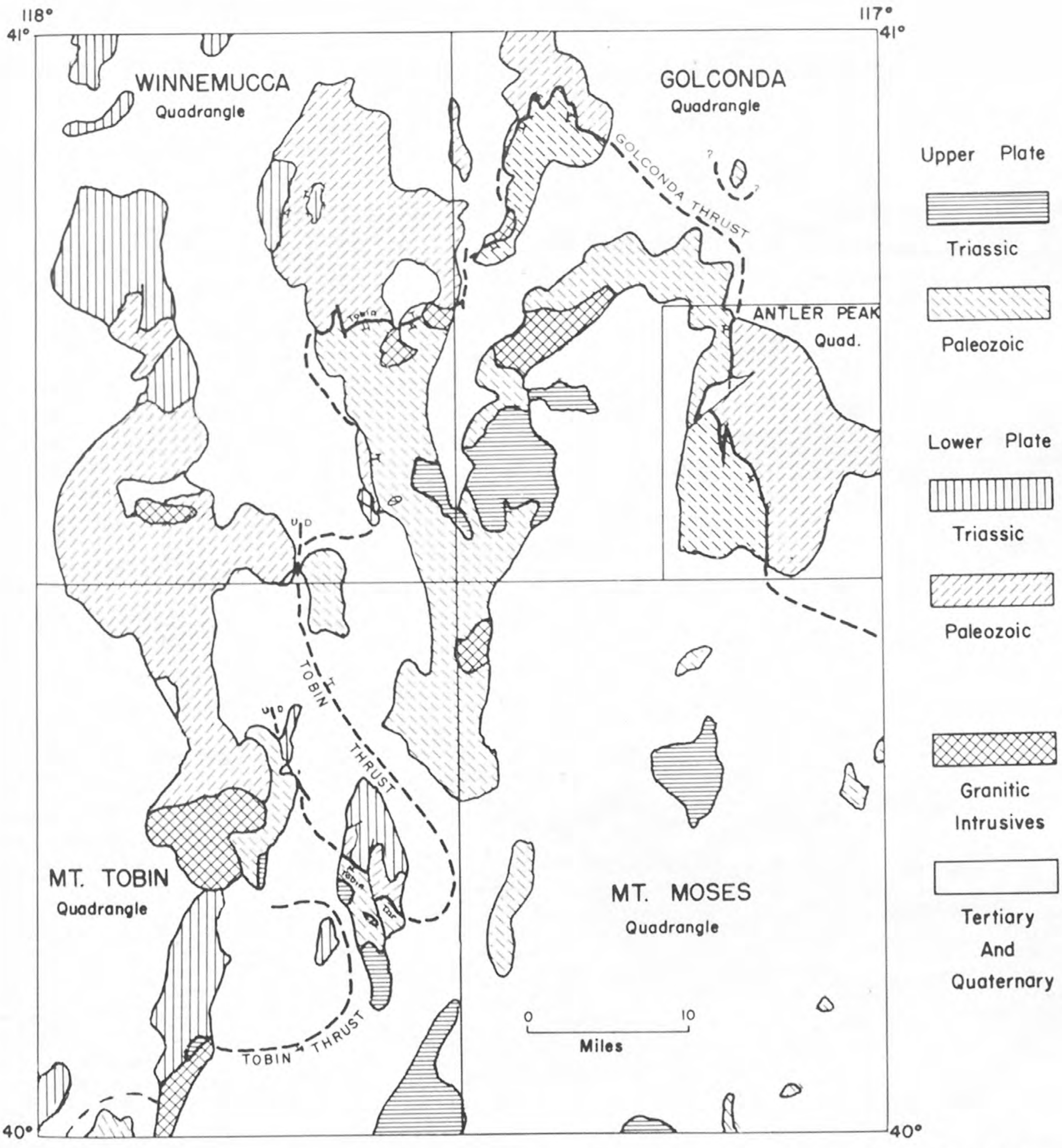


Figure 2. — Sketch map of the Sonoma Quadrangle, Nevada showing inferred extent of the Tobin-Golconda thrust

Extent of the Antler orogeny.--The full extent of the Antler orogeny is as yet conjectural. It is most clearly shown in Battle Mountain and in Edna Mountain, but it has also been recognized in the Osgood Range (Hobbs, 1948), about 20 miles north of Edna Mountain. The writer has also seen outcrops of conglomerate similar to the Battle formation in the Shoshone Range east of the Betty O'Neal mine resting unconformably on chert, argillite, and quartzite probably correlative with the Valmy formation. In the Sonoma Range at Clear Creek the Battle formation is missing, but the Antler Peak limestone rests unconformably on the folded strata of the Harmony formation. (Ferguson, Muller and Roberts.) These localities give a known extent of about 40 miles eastwest by 50 miles north-south, a total of 2,000 square miles. Further work will probably demonstrate that the orogeny is far more extensive.

In eastern and southeastern Nevada there is little evidence of much disturbance below the Mississippian other than the absence of uppermost Devonian or basal Mississippian beds. (Nolan, 1943, p. 172.) Nolan (1928, p. 171.) pointed out that a "late Paleozoic positive area"trending north-northeastward in central Nevada began to rise toward the end of the Devonian. Few detailed studies have been made along the site of the positive area. Near Candelaria, Ferguson and Muller (1949) noted that Permian sandstone rests on folded Ordovician rocks. Limestones of Pennsylvanian age south of Austin, Nevada, are reported to rest on slates and limy shales of probable Ordovician age (Ferguson and Muller, 1949). These unconformities represent orogenic movements as yet only approximately dated, but they may be in part equivalent in age to the Antler orogeny. Specific correlation will have to await detailed studies of the Paleozoic rocks in intervening areas. It is entirely possible, however, that the "late Paleozoic arch" was the site of an orogenic disturbance extending for 400 miles or more through central Nevada.

Near Burns, Oregon, Merriam and Berthiaume mapped Pennsylvania beds containing coarse clastics resting disconformably on lower Carboniferous beds. The exact age of the Pennsylvania beds could not be determined; it was concluded that it was lower Pennsylvanian, but that the possibility of upper Pennsylvanian could not be definitely ruled out. This disconformity might well reflect the fringe effects of the Antler orogeny.

In eastern Nevada the effects of the orogeny were only indirect. Near Elko, about 60 miles east of Battle Mountain, the writer collected Pennsylvania fossils from limestones interbedded with chert, quartzite, and pebble, conglomerate. The thickness of the section is not known, but it is estimated to be at least 2,000 feet, and may be much more. It is likely that the conglomerates were derived from the highland to the west and represent a marine facies contemporaneous with the upper part of the Battle formation and the Antler Peak limestone, but possibly deposited in another sedimentary basin.

Permian orogeny

While the Permian and older rocks in the lower plate facies were undergoing minor uplifts and erosion in this area, the Havallah formation and older rocks of the upper plate facies were being folded and thrust faulted in an orogenic episode here referred to as the Permian orogeny. The evidence for this orogeny is especially well shown on China Mountain (Ferguson, Muller, and Roberts). (See pl. 2.) Here the rocks of the Havallah formation are overlain unconformably by volcanic rocks of the Koipato formation. Because the Havallah formation contains fossils of Wolfcamp and Leonard(?) age and the Koipato formation is regarded as being equivalent to the Phosphoria formation (Wheeler, 1937), the orogeny took place within the Permian. The rocks of the Havallah formation were complexly folded, thrust faulted, and beveled by erosion before the outpouring of the volcanics of the Koipato. Certainly the unconformity between the Kaoipato formation and the overlying Triassic rocks is less striking for the angular unconformity between them is at most 20° and in places they are nearly parallel.

In the Antler Peak quadrangle, effects of the Permian orogeny are shown in the folds developed in the rocks of the Pumpernickel and Havallah formations. Near the Buffalo Valley mine the major fold is an anticline pitching gently southward. The fold is broken by several steep faults. Between Timber Canyon and Trenton Canyon the major structure appears to be a broad syncline upon which are superposed several minor folds. South of Timber Canyon the dips are for the most part westward, but on the west side of Rocky Canyon some minor tight folds are overturned to the east.

No faults were found in the upper plate of the Golconda thrust which could be assigned to the Permian orogeny, but probably both thrust and steep normal and reverse faults were formed at that time. Such faults would have been obscured by later faulting during the Mesozoic orogeny which occurred in the Jurassic.

Mesozoic orogeny

The Permian rocks of the lower plate facies in the Antler Peak quadrangle have been overridden by a thrust fault which has brought formations of the upper plate facies into the western side of the Battle Mountains. The orogenic movements that caused this later thrust faulting took place after the Permian, and as Jurassic rocks are involved in correlative thrusting in the Humboldt Range, the faulting must be Jurassic or younger. (Muller, S. W., personal communication, 1949.)

In Battle Mountain the Mesozoic orogeny is represented by the Golconda thrust fault, probably a continuation of a major thrust fault (Tobin thrust), which extends northwestward throughout Battle Mountain into Edna Mountain (see fig. 2), then turns southward just east of the Sonoma Range. It crosses the Sonoma Range at Clear Creek then continues south between the Tobin Range and East Range and finally crosses the East Range near Kinney pass, and is covered by alluvium from there southward. The Tobin thrust is discussed in more detail by Muller, Ferguson, and Roberts.

In the Battle Mountain the Golconda thrust passes diagonally northwestward through the range. A small segment of the thrust is exposed on the east side of Copper Canyon near the range front. From the Copper Canyon mine to the Nevada mine the thrust is downfaulted by normal faults and is not exposed. At the Nevada mine a short segment is exposed just north of the mine and the actual thrust surface can be seen. Here the footwall rock is chert conglomerate of the Edna Mountain formation and the thrust grooving is well preserved. The striae pitch westward and the thrust fault dips about 30°W. Elsewhere throughout Battle Mountain the Golconda thrust dips westward at angles probably between 20° and 60°.

From the Nevada mine to Willow Creek the thrust faults is buried at depth because it was displaced on a series of northward-trending normal faults. The next exposures of the thrust are in the valley of Willow Creek just above the upper spring in sec. 32, T. 32 N., R. 43 E.. Except for minor displacements and offsets along later normal faults, the thrust can be traced northwestward to the range front near the mouth of Cottonwood Canyon.

A steep thrust fault on the ridge west of Willow Creek duplicates part of the Havallah formation and may be an imbrication in the upper part of the Golconda thrust. (See pl. 2, sec. C-C'.) A reverse fault in secs. 6 and 7, T. 31 N., R. 42 E., brings up a narrow sliver of Battle formation and Antler Peak limestone. The contact with the Havallah formation on the west is a thrust fault, possibly a repetition of the Golconda thrust.

Folds

One of the striking features about the rocks near the thrust is that they appear to be only slightly deformed. The lower plate rocks belonging to the Battle formation and the Antler Peak limestone are very competent, and in Willow Creek and Cottonwood Creek west and northwest of Antler Peak near the thrust the only effect of the thrusting appears to be steep fractures in the limestone. The dip of the limestone appears to steepen near the thrust (see sections B-B' and C-C'), but is not overturned. In the Copper Canyon mine, however, the Battle formation dips steeply westward in the upper part of the workings; it becomes vertical, and then overturns to the east in the lower part of the workings. This major structure is probably related to the thrusting, and is strongly suggestive of movement of the upper plate from the west or southwest.

In the upper plate of the thrust on the ridge between Willow Creek and Copper Canyon minor folds in the chert of the Pumpernickel formation are overturned to the east; in addition, argillite layers show fracture cleavage overturned to the east. Whether these overturns are related to the Permian orogeny or to the Golconda thrust is not certain. It seems more logical at present to correlate them with the Permian orogeny.

Age of the thrusting

The age of the thrust faulting in north-central Nevada is a subject of considerable interest. Muller (personal communication, 1949), has studied Triassic and Jurassic rocks in Muttleberry Canyon in the Humboldt Range (about 50 miles west of the Battle Mountain), where they are involved in major overthrusting. Muller and Ferguson (1936) found that over-thrusting in the Hawthorne-Tonopah area took place during the lower Jurassic. The youngest rocks involved in the thrusting in the Sonoma Range quadrangle are Upper Triassic, so the thrusting is post-Triassic. It may be assumed that the thrusting is correlative with the thrusting in the Humboldt Range and therefore probably began in the early Jurassic.

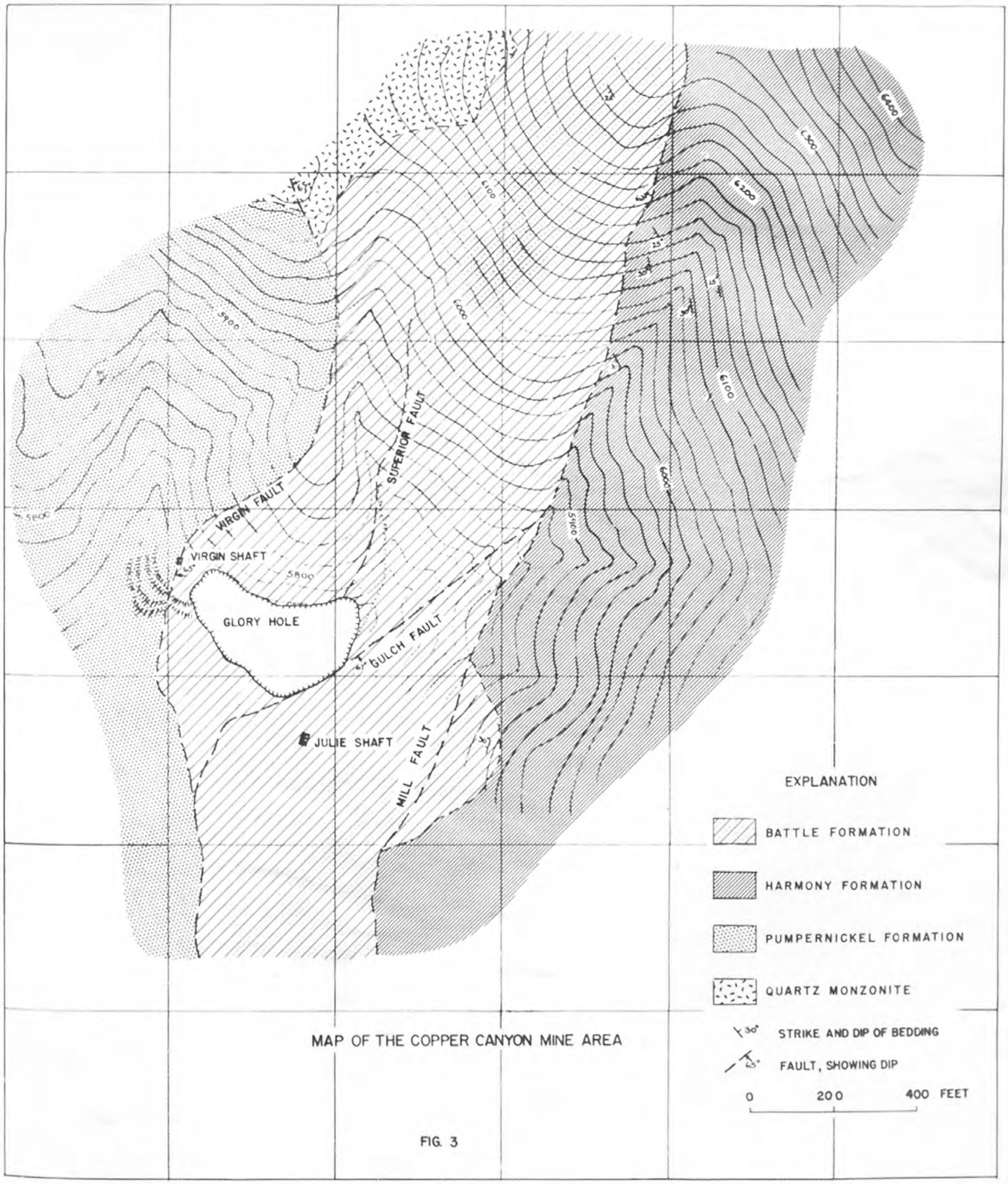
Nolan (cited by Merriam, 1942, p. 1706), reports that fresh water lower Cretaceous beds in the Eureka district, Nevada, are involved in thrust faulting, thus dating the thrusting as Cretaceous. Whether the thrust faulting in the Antler Peak area extended into the Cretaceous is conjectural. No beds are present which would aid in determination of the duration of the thrusting.

Steep normal and reverse faults.--The steep normal and reverse faults which cut across all of the folds and thrust faults were probably formed at several different periods, but principally followed the intrusion of the quartz monzonite and later rocks. Many of the faults are mineralized, and were channels for the mineralizing solutions which formed the ore deposits. It seems logical to assign all mineralized faults to this period for they are probably related to intrusives of the closing phases of the Mesozoic orogeny.

Most of the steep faults of Mesozoic age strike north and dip steeply. Faults striking northwestward and northeastward also were formed at this time. Some of these faults are well exposed in mine workings throughout the Battle Mountain district, and will be described briefly below.

Copper Canyon.-- In the Copper Canyon area the principal workings are along the Virgin, Estes, Superior, and Gulch faults. (See fig. 3.) The Virgin fault bounds the mineralized area on the west, and at the surface separated recrystallized chert of the Pumpernickel formation on the hanging wall from the Battle formation on the footwall. Just above the 300 foot level, the Golconda thrust, which separates the Pumpernickel formation of the upper plate from the Battle formation of the lower plate, is crossed in the workings. Below this point the Battle formation is present on both walls of the Virgin fault. Throughout the workings the fault strikes north and dips 60° -70° W. Its displacement is estimated to be about 1,200 feet 2 miles north of Copper Canyon. The Virgin fault is mineralized, both with primary and enriched copper ore bodies, and was productive during the early days of the camp.

The Gulch fault strikes N. 10° -30° E. and joins the Virgin fault south of the mine workings. In the workings the Gulch fault dips 55° -65° NW. Mineralization along the Gulch fault is sparse and no ore has been mined along it. The Estes fault strikes northwestward, diagonally between the Virgin and Gulch faults. Near the Virgin fault the Estes fault is nearly vertical, but as it extends downward into the mine it flattens to a dip of 34o -40o at the 500 feet level. The Superior fault strikes northward parallel to the Virgin fault, and dips 65° -70° W. The intersection of the Superior fault with the Estes fault



MAP OF THE COPPER CANYON MINE AREA

FIG. 3

does not show displacement, so the two faults probably formed at the same time. Both faults are mineralized, and have yielded high grade ore.

Galena Canyon.--In Galena Canyon the Trinity, White and Shiloh, and Butte mine workings explore major north-trending faults. All of these faults dip steeply to the west, and appear to have normal displacement. The amount of displacement is seldom determinable, but the upper plate of the Dewitt thrust is downthrown on the Trinity fault; the displacement is at least 500 feet, and may be as much as 1,500 feet.

Copper Basin.--In Copper Basin most of the mines are situated on north-trending faults, but some faults striking northwestward are also mineralized. In the Contention and Sweet Marie mines the ore is in part controlled by faults of low dip which may be thrust faults. The low-dipping faults are cut by the steep normal and reverse faults.

Tertiary and Quaternary orogeny

North-central Nevada was probably undergoing uplift and erosion during the late Mesozoic. The major structures which outlined the ranges and the valleys may have developed in the late Mesozoic or early Tertiary. Local basins in which continental deposits were laid down probably existed, but no such deposits are exposed in the Battle Mountain area. If sedimentary deposits of early Tertiary age were laid down in the valleys, they are now covered by younger sediments.

The principal sites of Tertiary sedimentation in north-central Nevada were probably the valleys. The evidence for this is that the sediments of Tertiary age are confined largely to the present valleys. Locally sediments and volcanics of Tertiary age form the low ranges, and occur as cappings on the older rocks, but commonly the Tertiary rocks are more abundant around the foothills and lower slopes of the major ranges. One of the early basins was near Elko, about 70 miles to the east; the first beds deposited were lake sediments, oil shales, and fresh water limestones formed in a humid climate; as deposition continued the climate became less humid, and the later sediments are coarse clastics and lake deposits formed in an arid climate. (Sharp, 1939). Ferguson (personal communication), considers that through-flowing drainage to the Pacific existed during a considerable part of Quaternary, but it is likely that vulcanism and orogeny interrupted the major drainage lines from time to time.

The courses of the Humboldt and Reese Rivers show evidence of such interruptions for both streams flow alternately in broad valleys, probably structural in origin, and in narrow gorges such as Emigrant Canyon. (See plate 3.) The narrow gorges are largely in volcanic and pyroclastic rocks of mid- or late Tertiary age, and indicate that the vulcanism caused diversions of the streams through Tertiary basins. As cutting down took place, the streams were superposed upon hard strata or volcanic rocks; they were able only to cut narrow gorges through the harder layers, and have not been able to bring their profiles to grade since then.

Steep normal and reverse faults

The steep normal and reverse faulting which began in the Mesozoic following the intrusion of the quartz monzonitic and granodioritic rocks, probably continued into the Tertiary. It is entirely likely that recurrent movement took place on some of the old faults at widely separated periods. Faults definitely assigned to the Tertiary, however, belong to three principal sets. The oldest set trends eastward; this set is cut by conjugate faults which strike northwestward and northeastward; the youngest faults are north-trending and cut the older faults.

The eastward trending faults are most easily recognized where they displace rocks of Tertiary age such as the rhyolite flows. In Copper Basin near Elephant Head (pl. 2) faults trending N. 70° E. to N. 70°W. displace the rhyolite and older rocks. Generally these faults cannot be traced far for they are cut off by later faults, but some of them appear to have displacements estimated to be as much as 200 feet. The downthrown side on these faults appears to be chiefly on the north, but many of them bound graben or horst blocks.

The faults trending northwest and northeast are a conjugate system . Faults of this system outline the range on the east and northeast, and separate the foothills west of North Peak from the main range. In most places all traces of the original fault scarps have been removed by erosion, but where soft rocks have been eroded altogether, prominent fault-line scarps are shown. These fault-line scarps are discontinuous because deep canyons have been cut through them, but the alinement of the spur ends is still impressive. Movements on these faults probably continued into the Quaternary, for they cut the fan deposits of that age which flank the range.

The youngest faults are north-trending faults which cut both sets of older faults and bound Battle Mountain on the west. Faults belonging to this set cut the fan gravels (Qoa) flanking the range but do not generally displace the youngest deposits (Qya). The faulting therefore took place during and after the main period of fan formation, but prior to the dissection of the fans.

At the Buffalo Valley mine the workings cut through the range front fault. Here the fan gravels (Qoa) are faulted down against the limestones, quartzites, and cherts of the Havallah formation. The fault strikes about N. 10°E. and dips 50° NW. The zone of shearing along the fault is 10 to 15 feet wide, and the gravels show a kind of sheeting parallel to the fault. The rocks of the Havallah formation in this area are silicified and fractured, but not otherwise disturbed along the fault. At depth the Havallah formation is probably present in both blocks of the fault.

GEOMORPHIC HISTORY

The land forms which make up Battle Mountain and surrounding areas came into existence principally during the Tertiary, and were sculptured and modified by erosion throughout the Quaternary. Because the process of sculpturing took place over a long period of time, and seems to have involved several cycles, a historical treatment of the origin of the land forms will be attempted here.

The history of Battle Mountain following the retreat of the seas in the Jurassic is not known. It may be inferred that, during the orogenic movements beginning early in the Jurassic and possibly extending into the late Mesozoic, the region became a landmass undergoing uplift and erosion. Volcanic activity may well have begun in the early Tertiary (Nolan, 1943, p. 163), but the first volcanic rocks which can be assigned to a definite period are the rhyolites on some of the ridges in the southwestern, central, northwestern and eastern parts of the range and are correlated with rhyolites near Elko, Nevada which are considered to be Miocene. (Sharp, 1939.)

The rhyolites flowed out on a mature surface of moderate relief, in places on an old soil developed on the older rocks. In other places the rhyolites rest on tuffs and washed gravels. It is likely that the range was then outlined in its present form, but had a much lower relief than now. Uplift along the range front faults probably continued during the Pliocene. Basaltic volcanics which were extruded along the margins of the range flowed into valleys, but did not extend far into the ranges. As the basalts are now found only on the flanks, it seems likely that the range was higher than during the extrusion of the rhyolite.

The events following the Tertiary volcanism must be deciphered from the land forms now preserved in the range. Four major stages in the development of the range can be recognized, beginning probably in the late Pliocene and extending to the present. Listed in order of their age they are as follows: (1) mature upland stage, (2) canyon cutting and fan building stage, (3) fan dissection stage, and (4) lake state.

Mature upland stage.--The mature upland stage is preserved in the central parts of the range. It is characterized by broad valleys and ridges and a surface of low relief, probably not exceeding 1,500 feet, and generally less than 1,000 feet. An old soil profile--deeper than present desert soil profiles--was developed on the younger volcanics as well as upon the older rocks. This old soil is now preserved on the broad interstream areas in the central part of the range, but has been stripped from the dissected canyon areas. Probably the climate during the formation of the mature upland stage was more humid than now, and the region had external drainage.

Canyon stage.--The canyon stage was probably initiated by uplift, and was accompanied by a change of climate to one of less humidity, or at least to one of more seasonal rainfall. The canyons were deeply incised in the mature upland, and the debris eroded was deposited on the flanks of the range as broad fans. The uplift probably continued intermittently during this stage, for the fans are in places faulted and there is evidence of continued movement along the range front faults.

The second stage ended with the building of the broad fans, but toward the end of the stage the streams were evidently overloaded, for the valleys were aggraded, and fill extended headward several miles into the range. The filling was as much as 200 feet deep at the range front. A renewal of uplift or a climatic change to more torrential rainfall could have caused the beginning of the third stage--dissection of the fans. The dissection has resulted in the formation of terraces in the principal valleys, and cutting of deep channels into the fans. The channels extend out from the range as far as 2 miles; at the range front the channels are 50 to 150 feet deep, 100 to 300 feet wide, and become wider and shallower away from the range. The third stage probably overlapped with the fourth stage, the lake stage.

In the Buffalo valley the lower parts of the fans have been reworked by wave and current action up to an altitude of 4,640 feet. In many places well-marked shorelines and beach and offshore bars are present, indicating the former presence of a lake which probably existed at the same time as Lake Lahontan during late Quaternary time. (Antevs, 1925.) Since the formation of the lake features, erosion has been slight in the area. The bars are cut by shallow rills and locally by channels, but otherwise they are essentially unmodified from their original form.

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Photograph by H. G. Ferguson

Airplane view of the Battle Mountains from the southeast. Placer workings on the Copper Canyon fan are at the lower left.

Photograph by Lloyd Henbest

Antler Peak from the southeast. The base of the Antler Peak limestone is just below the cliffs. The limestone beds on the left are separated by a fault from the sequence exposed on the peak. The smooth slopes in the middle distance and foreground are underlain by pebble and cobble conglomerates and shales of the upper part of the Battle formation.

Photograph by Lloyd Henbest.

View looking south from the Battle Mountains near Antler Peak. Mature upland cut on Battle formation in right foreground, slopes leading down into Galena Canyon on left. The Reese River valley extends south between Shoshone Range on the east, and the Fish Creek Range on the west. Part of Buffalo Valley can be seen between the Battle Mountains and Fish Creek Range.

View looking southeastward down Cow Canyon into Galena Canyon. The snow capped range in the distance is the Shoshone Range. The outcrops in the foreground are Battle conglomerate.

A. View looking eastward up the Humboldt Valley from North Peak. The town of Battle Mountain is a dark spot in center of valley in middle distance.

B. View looking southeastward from North Peak across the mature upland of the Battle Mountains.

Photograph by Lloyd Henbest

View looking northward to the ridge between Cow Canyon and Galena Canyon. Shows folded strata of the Harmony formation. The beds on the left are folded in a syncline whose east limb dips about 40°W. and whose west limb is overturned to the eastward.

A. View looking northward from a point several hundred feet south of point from which Plate 10 was taken. Shows folded strata of the Harmony formation in center and east sides of ridge. On west side the steep cliffs are conglomerate of the Battle formation dipping gently westward.

B. Basal facies of Battle formation showing boulders of Harmony sandstone. Note lack of sizing and rude bedding. Scale is about 6 inches long.

A. Contact of chert of Scott Canyon formation and conglomerate of the overlying Battle formation in Cottonwood Canyon. Note rounding of pebbles in the conglomerate. Scale about 3 inches long.

B. Contact of sandstone of the Harmony formation and conglomerate of the overlying Battle formation. The head of the geologic pick marks the contact. Shows lack of sizing in conglomerate; some fragments are rounded, others subangular.

A. Polished specimen of conglomerate from Battle formation. Shows part of boulder of quartzite on right in matrix of sand and pebbles. Pebbles are chiefly chert and some quartzite. Natural size.

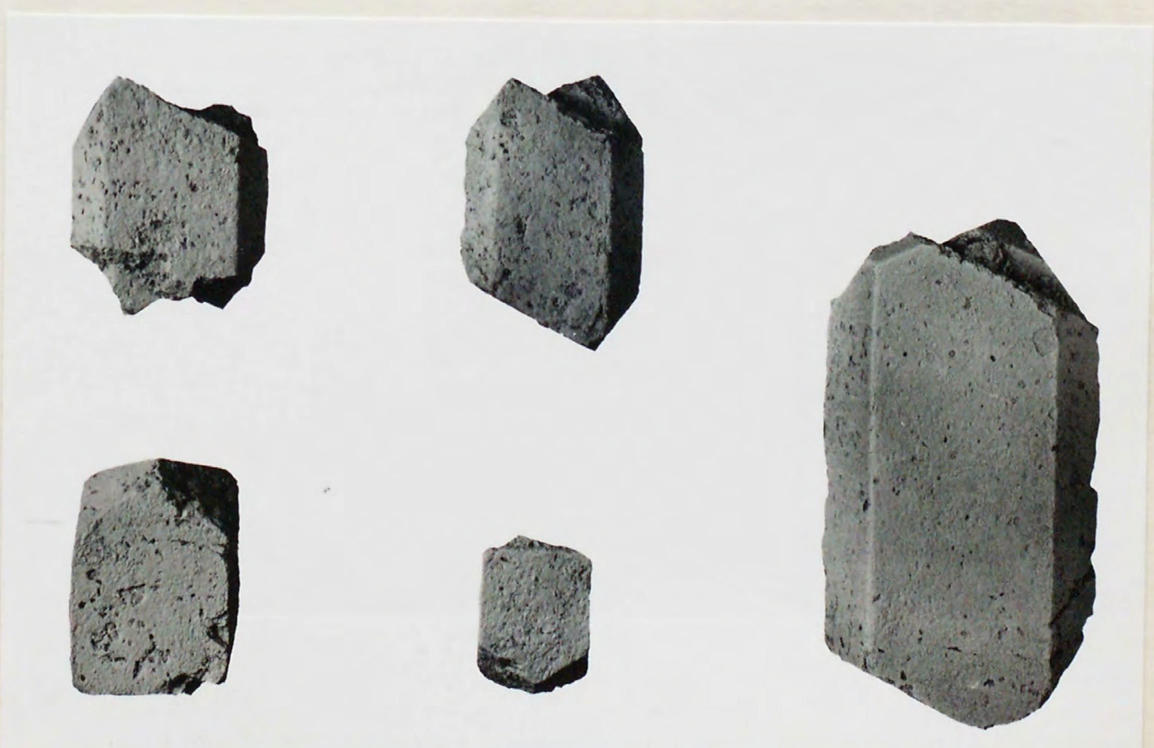
B. Outcrop of Harmony sandstone showing sharp fold. Geologic pick is at axis of fold where beds turn up vertically.

A. Photograph showing characteristic bedding in the Copper Canyon fan at the range front. Note channelling and extreme variation in amount of sorting. The hammer is about 14 inches long.

B. Photograph showing poor bedding in the Copper Canyon fan at the range front. The middle layer is composed of angular chert fragments and contains little matrix; the upper and lower layers are composed of chert fragments in clayey and silty matric. The hammer is about 14 inches long.

Plate 15.

A. Photograph showing gravel in basal part of Copper Canyon fan about a half mile from the range front. Outcrop in lower left is chert and argillite upon which the fan was deposited. Note the poor sorting and the angularity of the fragments of chert in the fan gravels. The hammer is about 14 inches long.



B. Orthoclase phenocrysts weathered from quartz monzonite porphyry in Copper Basin. Crystal on right and upper two crystals are Carlsbad twins. Natural size.

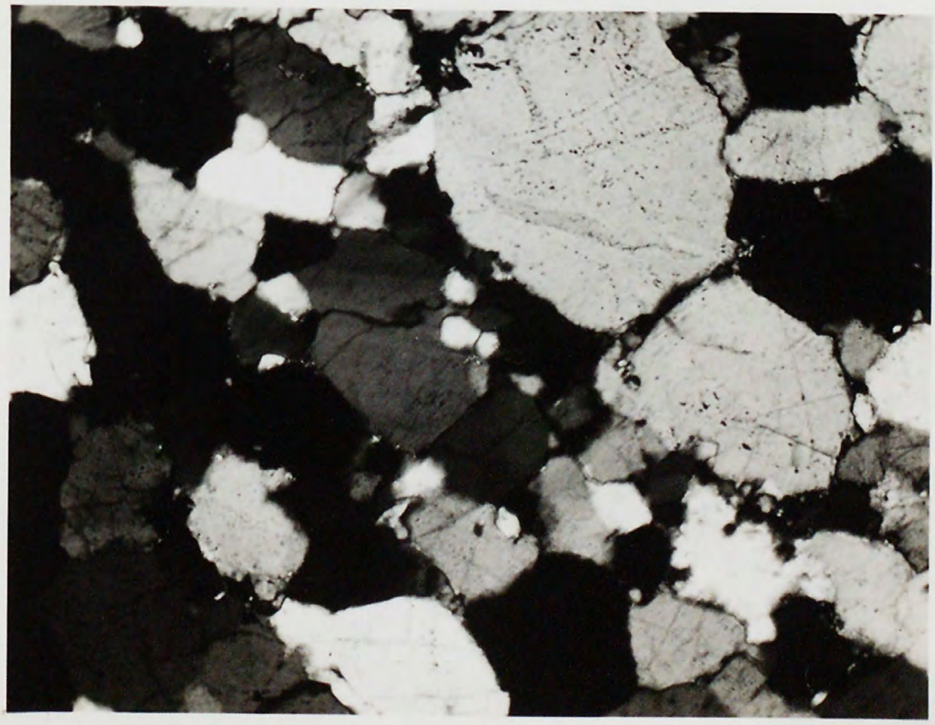
Plate 16.

Polished specimens of folds in cherts of the Scott Canyon formation. Natural size.

A. Granodiorite from Elder Creek. Shows phenocrysts of plagioclase in a groundmass of orthoclase, quartz, plagioclase, biotite, and hornblende.

B. Quartz monzonite porphyry from dike southeast of Copper Basin. Shows phenocrysts of quartz, plagioclase, hornblende, and orthoclase in a fine-grained groundmass.

A. Banded chert, Scott Canyon formation. Light-colored bands contain more clastic quartz than darker bands. Plane-polarized light. x53.



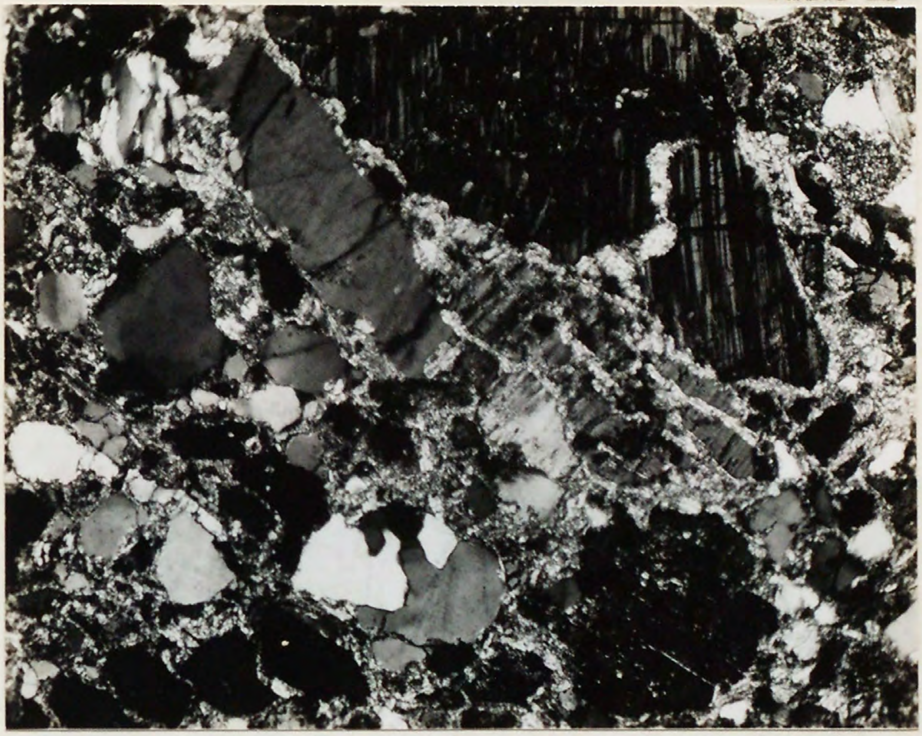
B. Quartzite, Valmy formation. Shows seriate quartz grains; grain boundaries, generally smooth, locally sutured. Crossed nicols, X75.

A. Contact of greenstone flow and chert, canyon south of Duck Creek. Shows argillitic chert (right), fibrous and radial chalcedony (center); secondary albite and quartz aggregates (left center and upper center). Crossed nicols x53.

B. Same, plane-polarized light. x53.

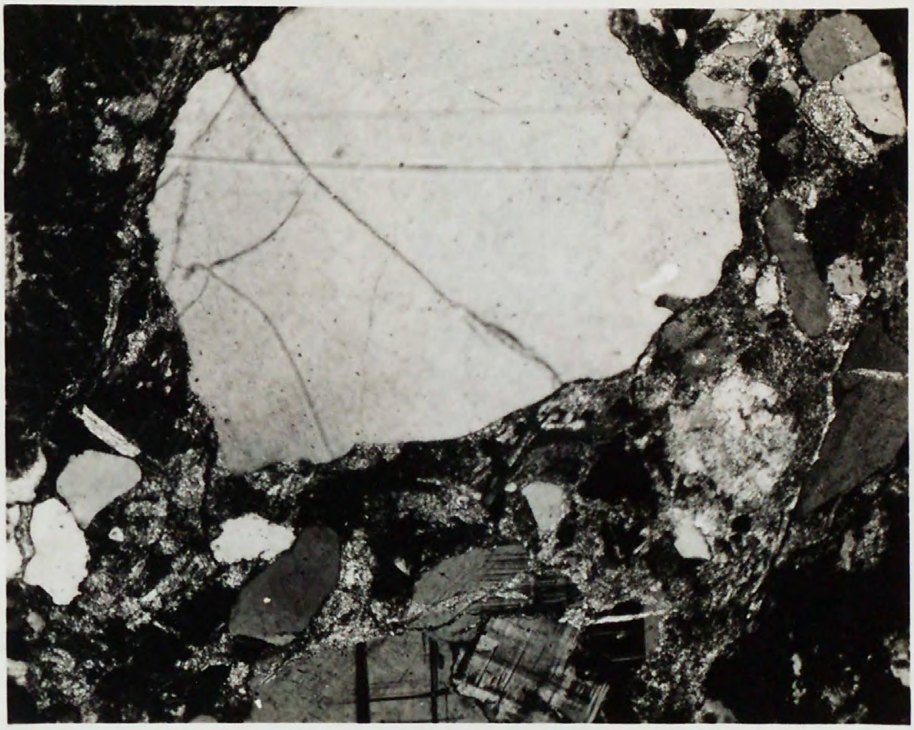
A. Greenstone, Galena Canyon. Showing lens of secondary albite and actinolite in altered groundmass of greenstone. Plane-polarized light. x75.

B. Same, crossed nicols. x75.

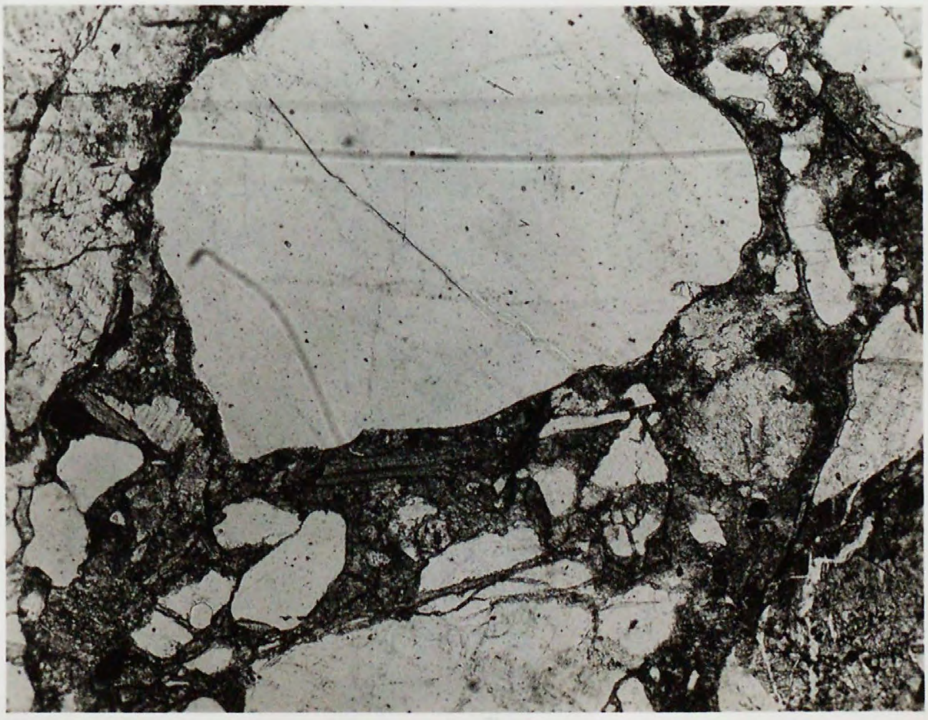


A. Sandstone of the Harmony formation. Shows microcline (upper center), quartz, and orthoclase grains in groundmass of mica and argillaceous material. Crossed nicols. x53.

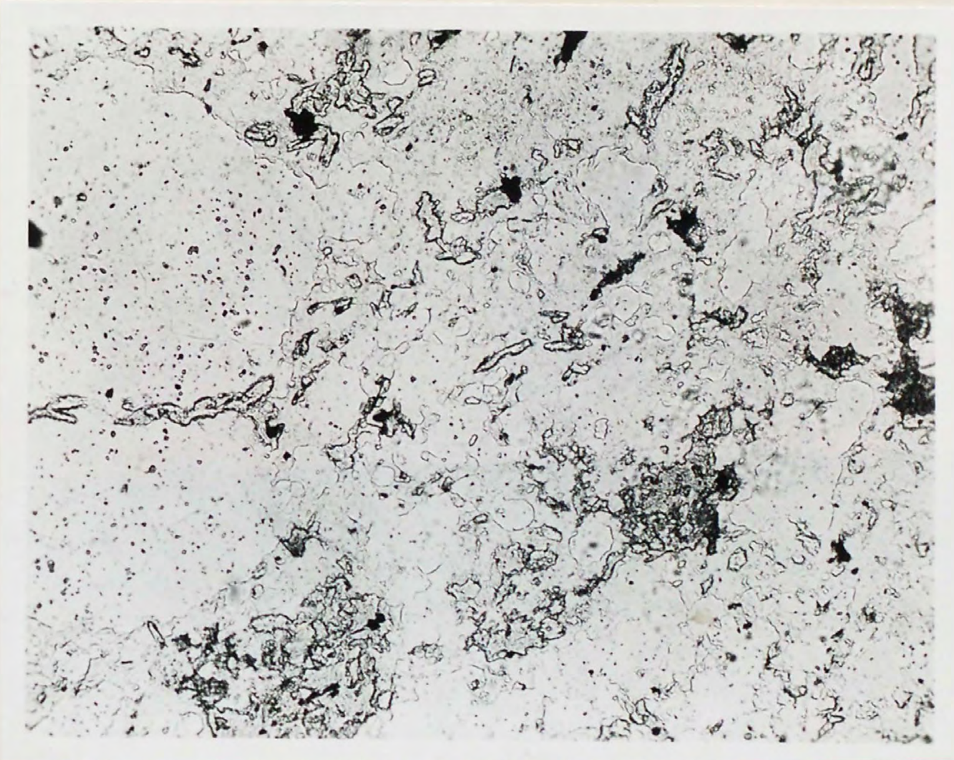
B. Same, plane-polarized light. x53. Note angularity of fragments and freshness of feldspars.



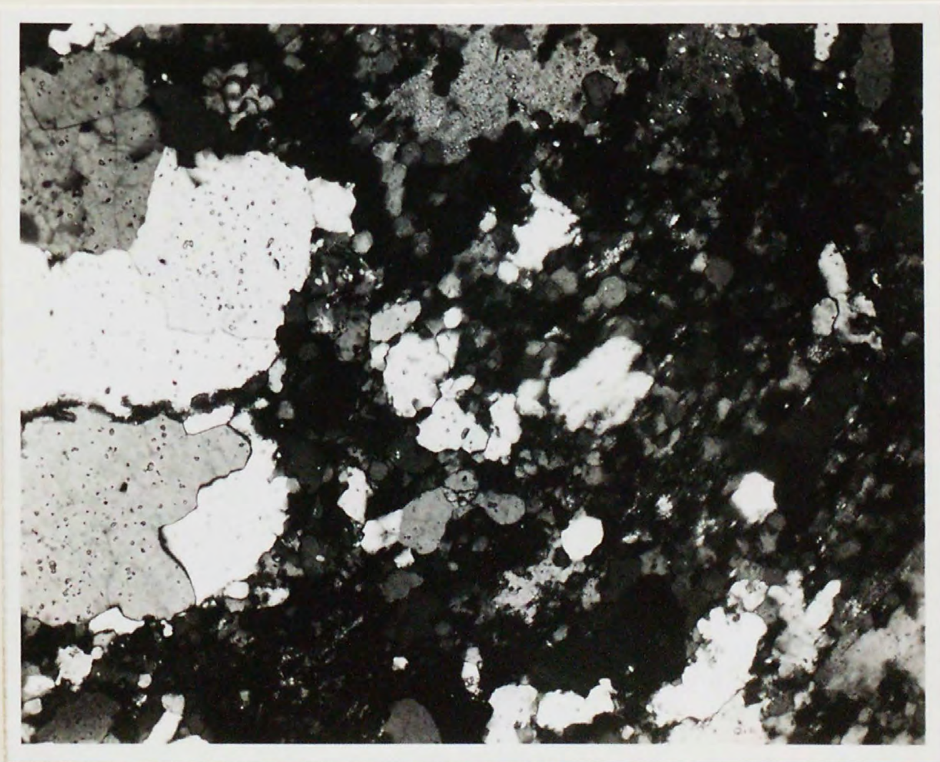
A. Sandstone of the Harmony formation, Cottonwood Canyon. Shows quartz and microcline grains (lower center) in calcareous and argillaceous groundmass. Crossed nicols. x 53.



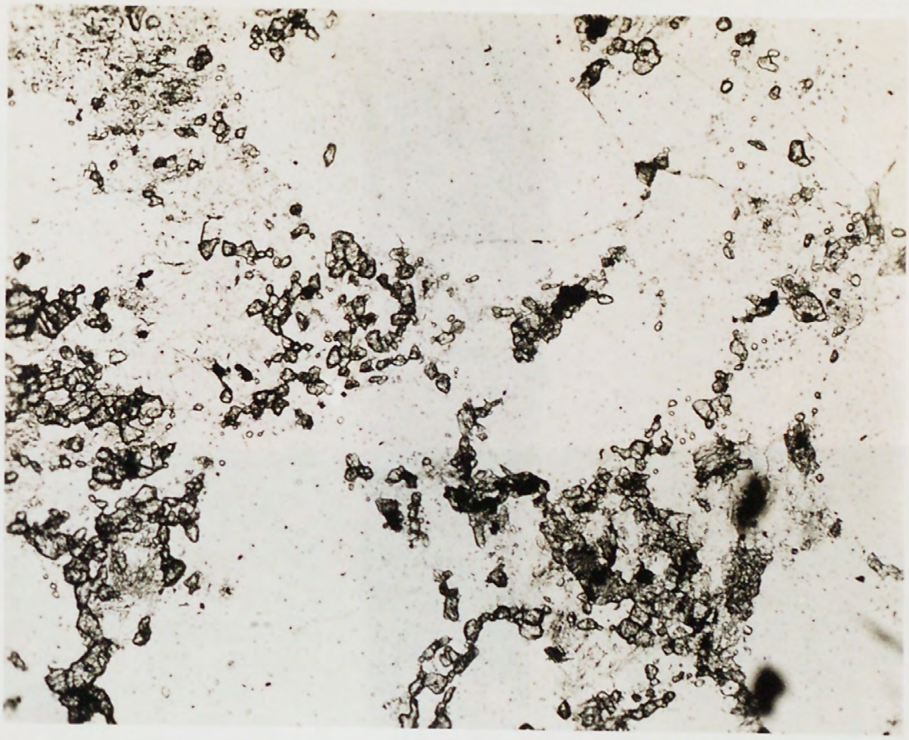
B. Same, plane-polarized light. x53. Note biotite flake just below large quartz grain.



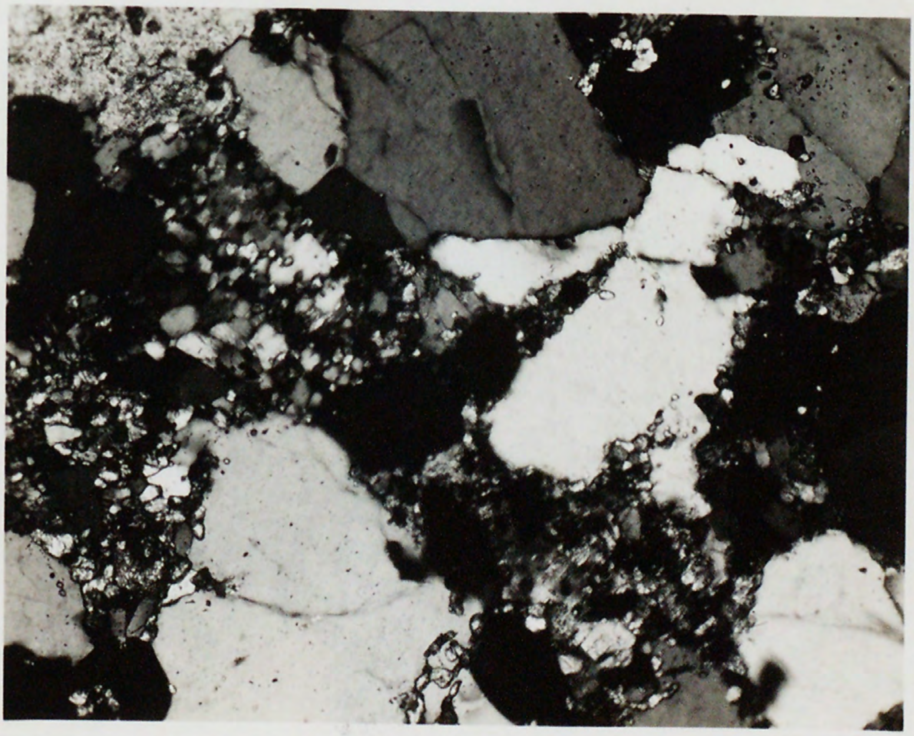
A. Metamorphosed sandstone of the Harmony formation Copper Canyon. Shows quartz, (left, center, and lower part) in a groundmass of orthoclase and chlorite (high relief and dark gray). Black grains are pyrite. Plane-polarized light. x75.



B. Same, crossed nicols, x75.

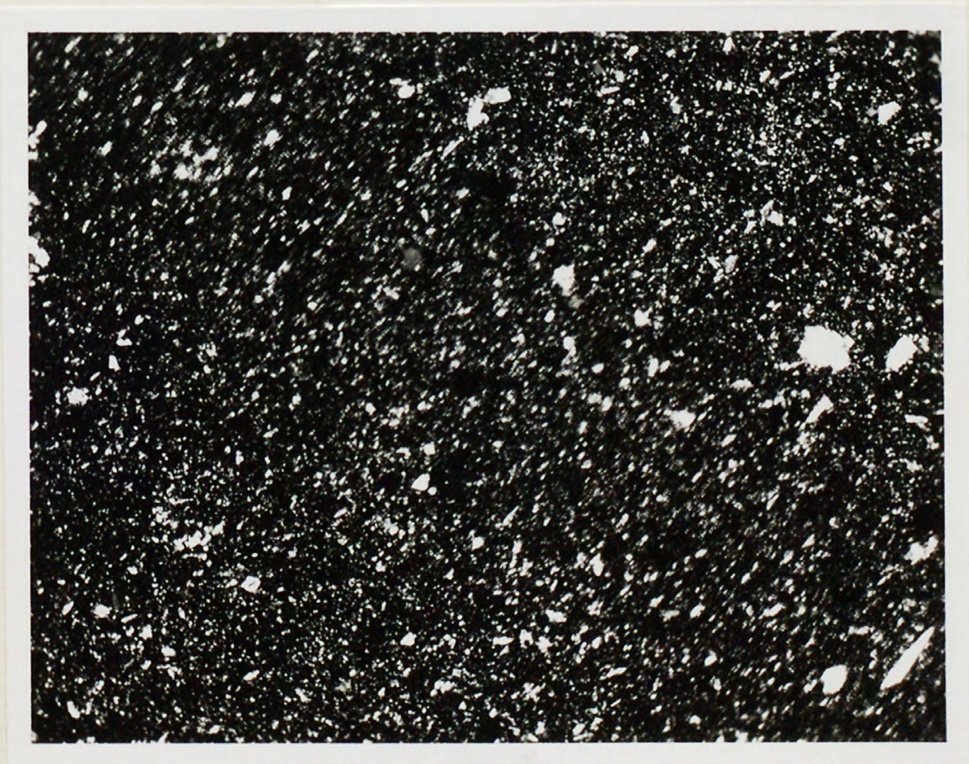


A. Metamorphosed sandstone of Harmony formation. Shows quartz grains with interstitial diopside and orthoclase. Plane-polarized light. x75.

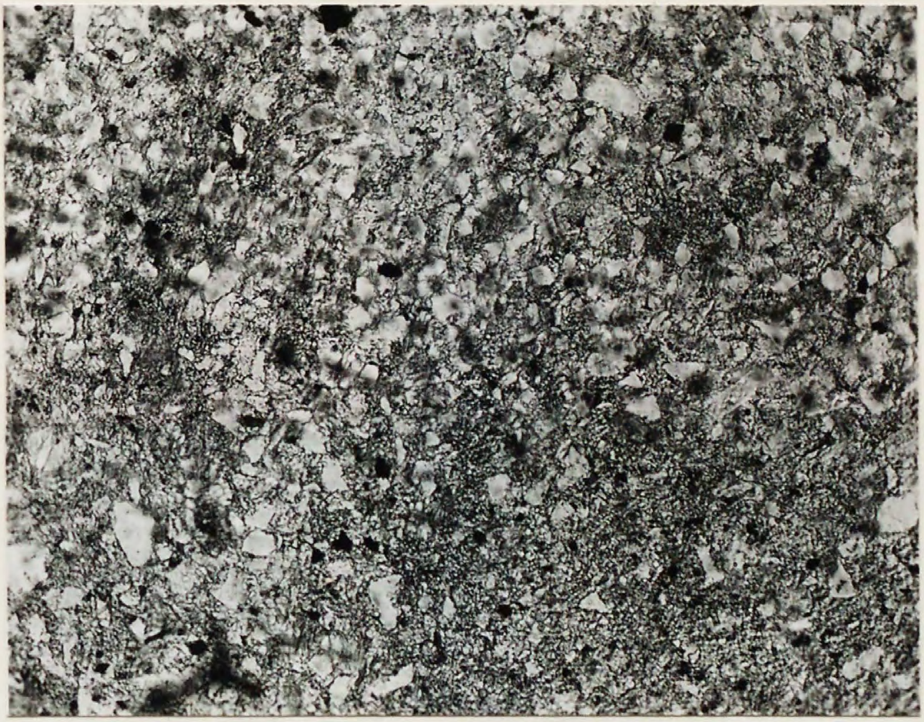


B. Same, crossed nicols. x75. Shows turbid orthoclase (upper left), grano-blastic quartz between clastic grains.

A. Chert of the Pumpernickel formation. Shows round or elliptically shaped areas slightly clearer than groundmass which may be radiolaria. Plane-polarized light. x75.



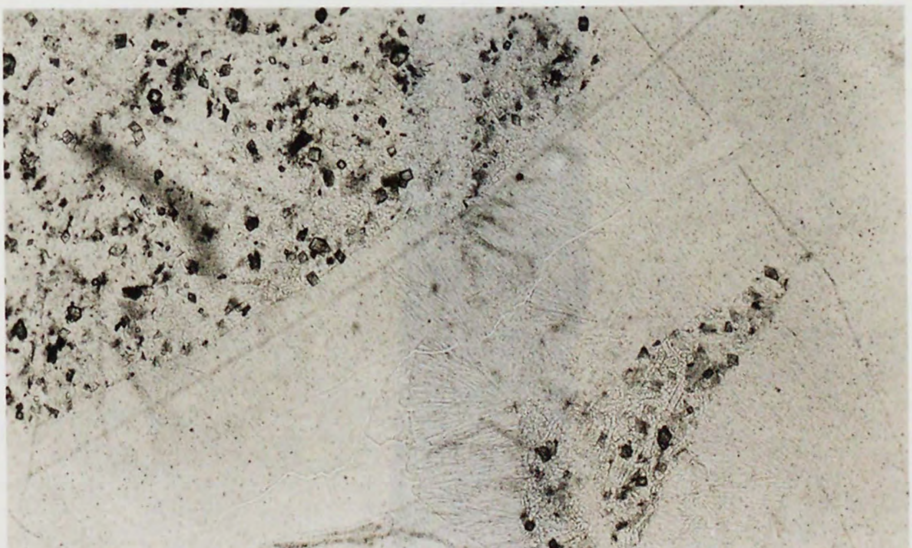
B. Same, crossed nicols. x75. Shows clastic quartz grains in chert groundmass.



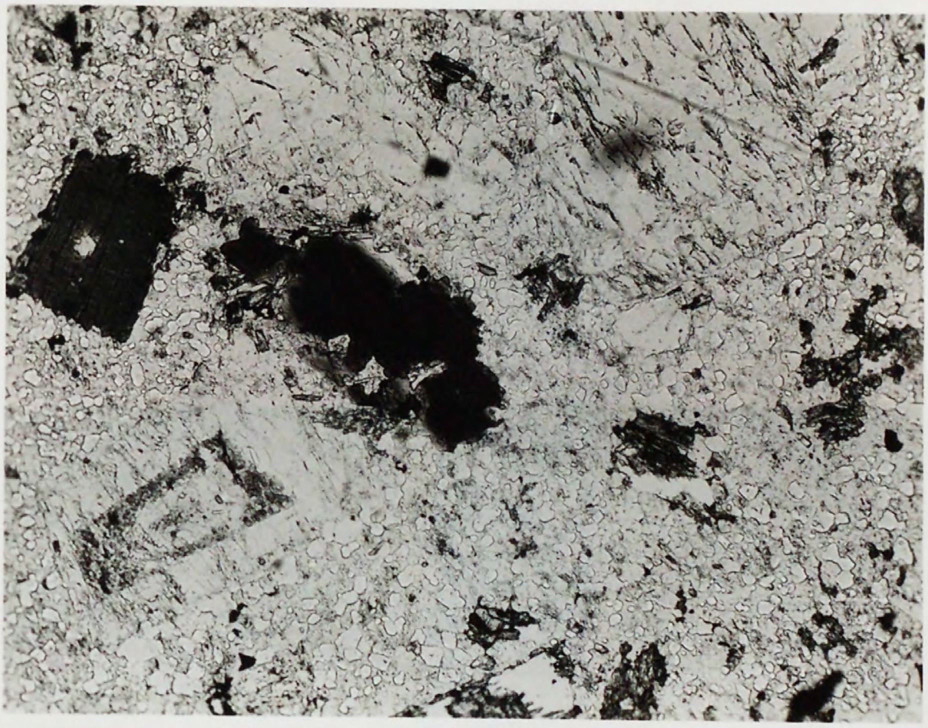
A. Argillite of the Pumpernickel formation, Willow Creek. Shows angular quartz grains in an argillaceous groundmass. Plane-polarized light. x75.

B. Same, crossed nicols. x75.

A. Chert of the Pumpernickel formation. Shows chalcedony vein with quartz in central part. Crossed nicols. x53.



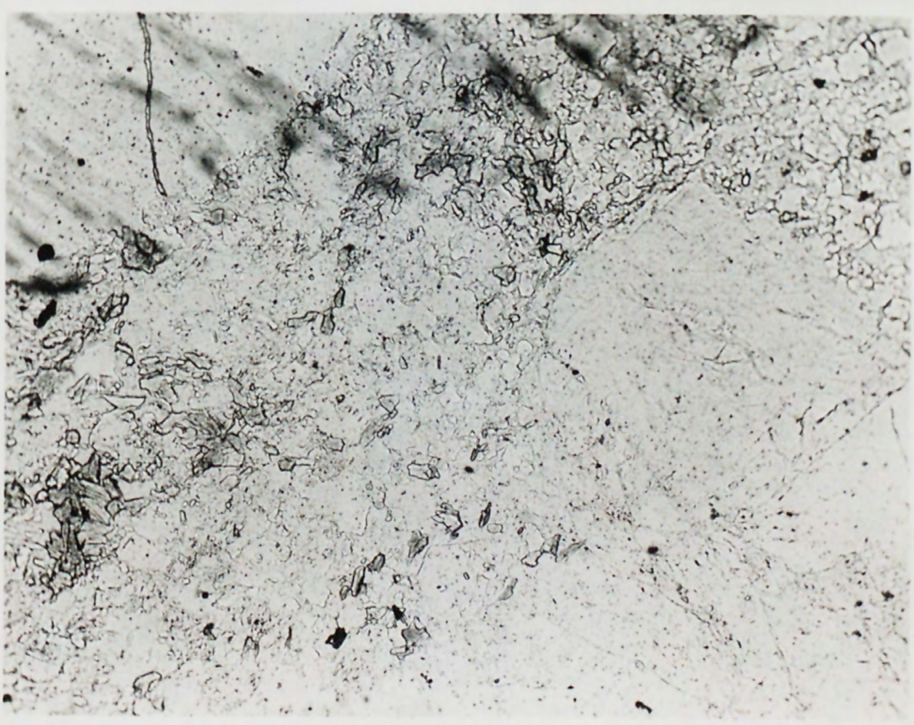
B . Same, plane-polarized light. x53. Shows calcite rhombohedrons in the chert.



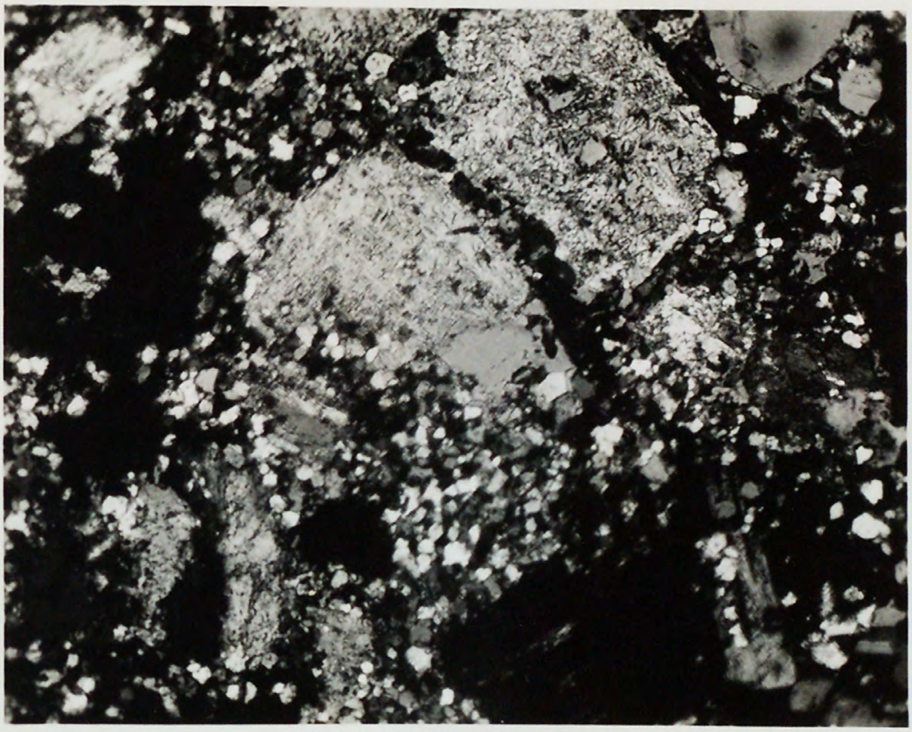
A. Quartz monzonite porphyry, Copper Canyon. Shows plagioclase and biotite phenocrysts in a fine-grained groundmass of quartz and orthoclase. Note zone of alteration to clay minerals in the plagioclase crystal (lower left). Plane-polarized light. x53.

B. Same, crossed nicols. x53. Note how quartz and orthoclase of groundmass penetrate the plagioclase crystals along boundaries.

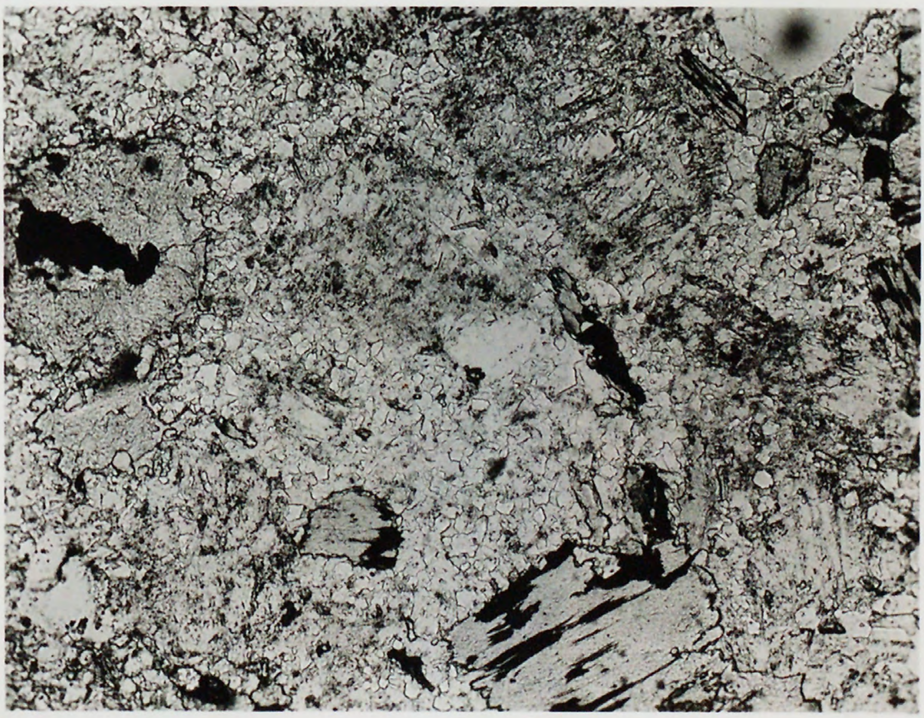
A. Quartz monzonite porphyry dike, Copper Canyon mine. Shows plagioclase phenocrysts in a groundmass of quartz, orthoclase, and biotite. Crossed nicols. x75.



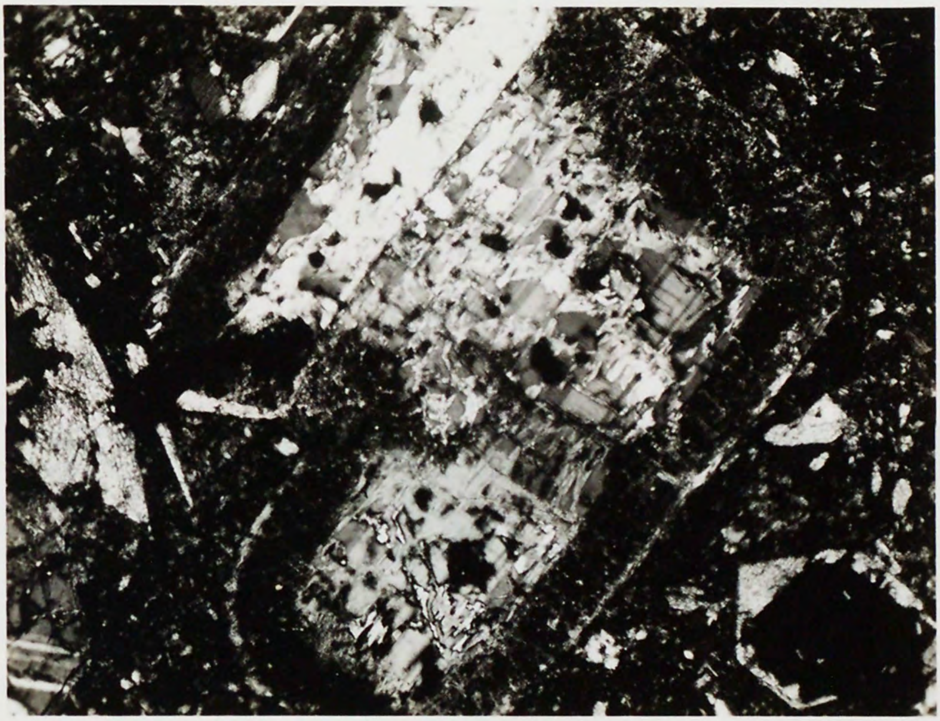
B. Same, plane-polarized light. x75. Note embayed borders of the phenocrysts.



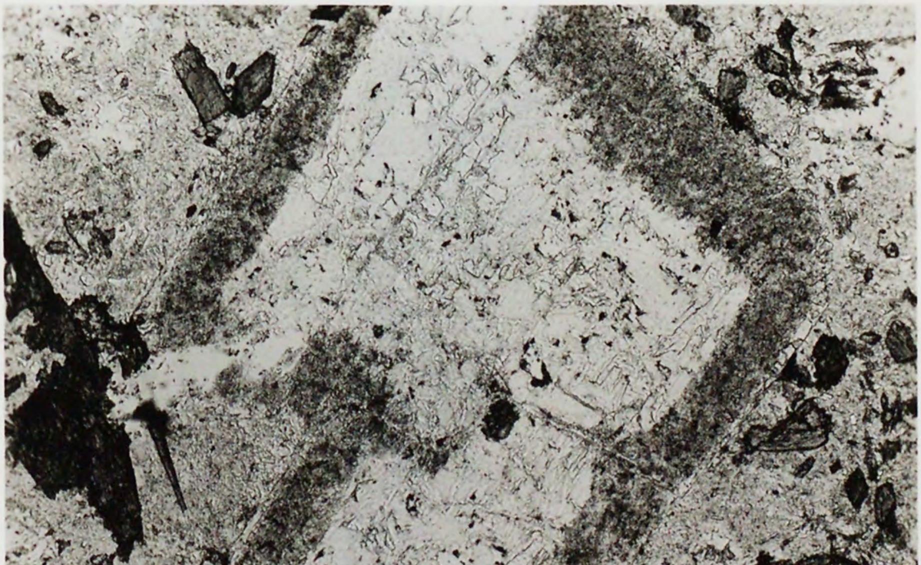
A. Granodiorite, Elder Creek. Shows plagioclase phenocrysts (upper center and lower left) in a groundmass of quartz, orthoclase, and chlorite after biotite (black). Cross nicols. x53.



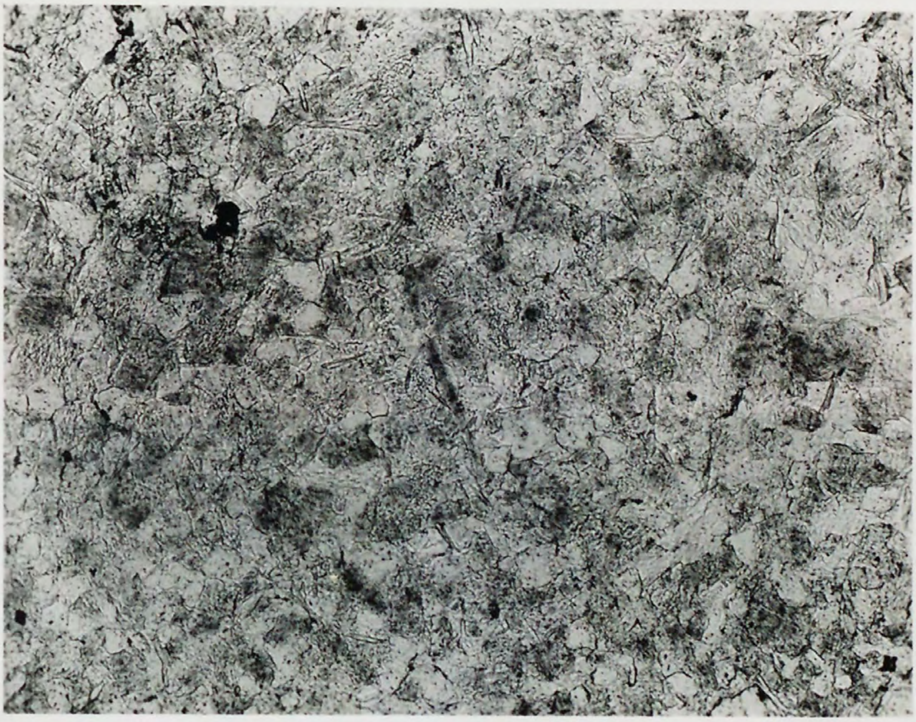
B. Same, plane-polarized light. x53. Note that orthoclase partly replaces the plagioclase phenocrysts. Dark areas in chlorite are iron oxides and a mixture of epidote and zoisite.



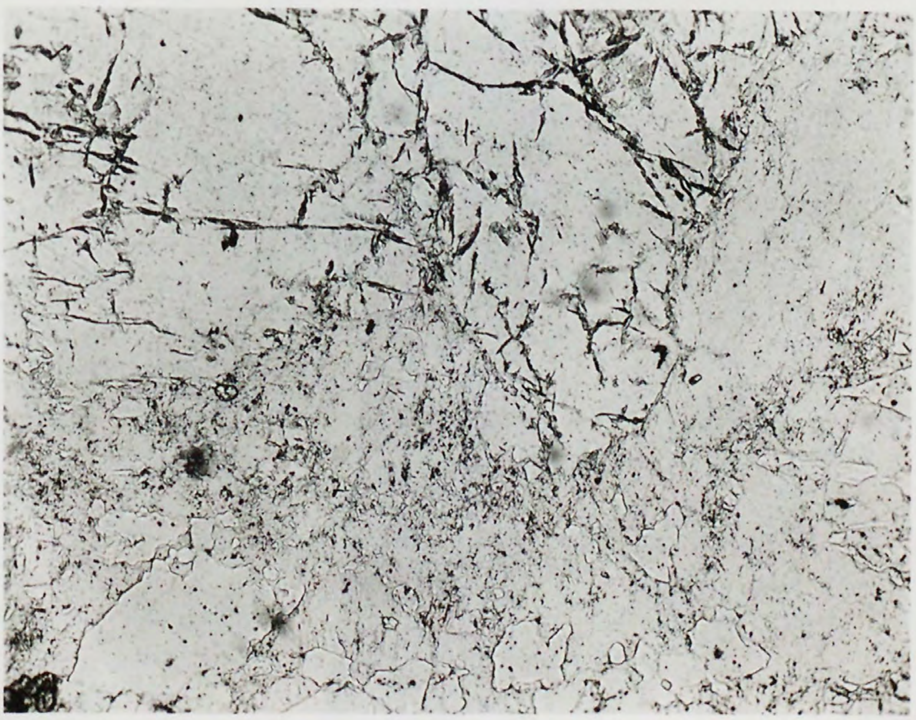
A. Granodiorite porphyry, showing plagioclase phenocrysts partly replaced by orthoclase and with an outer turbid zone of alteration to clay minerals. Crossed nicols. x53.



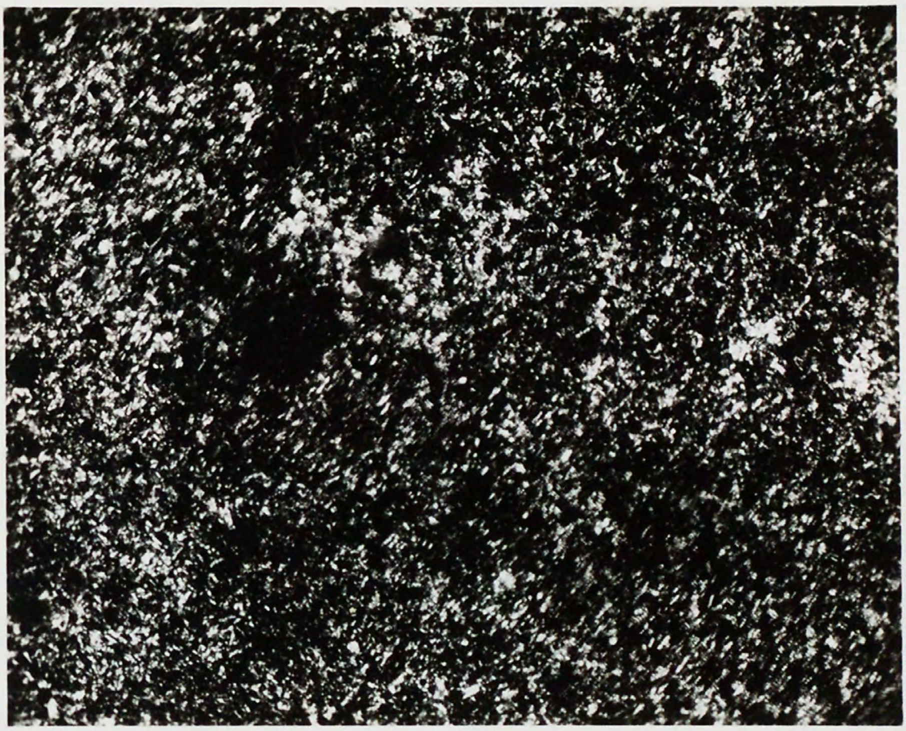
B. Same, plane-polarized light. x53. The mafic mineral is hornblende.



A. Quartz monzonite porphyry, Cottonwood Canyon. Shows groundmass of quartz (clear) and orthoclase (turbid). A few wisps of muscovite are scattered throughout the section. Plane-polarized light. x75.



B. Granodiorite, Trenton Canyon. Shows plagioclase (upper part) partly replaced by orthoclase (low relief); quartz grains (lower part and right) stand out in relief. Plane-polarized light. x75.



A. Rhyolite, west side of Willow Creek. Shows glassy groundmass with bands of spherulites alined parallel to flow lines. Phenocrysts are quartz and biotite. Plane-polarized light. x53.

B. Hornfels of the Pumpernickel formation, showing shreds of mica, fine-grained quartz in a still finer groundmass. Crossed nicols. x75.

pocket contains 3 folded maps

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