THE SILVER CITY QUARTZITES: A KANSAS METAMORPHIC AREA ¹

BY W. H. TWENHOFEL

(Presented before the Society December 27, 1916)

CONTENTS

	Page
Introduction.....	419
Geology of the Silver City area.....	421
The local section.....	421
Lawrence shales.....	421
latan (Kickapoo) limestone.....	421
Le Roy shales.....	422
Stanton limestones.....	422
The Silver City anticline.....	422
Detailed geology of Silver City ridge.....	422
Summary of the data.....	427
Causes of the alteration.....	428
Relation of the altered rocks to the lead and zinc deposits of southeastern Kansas, the Rose boulders, and the granites reported from deep wells of central Kansas.....	429

INTRODUCTION

The Pennsylvanian section of Kansas and neighboring States is widely known for the essentially unaltered character of the composing sediments and the supposed absence of any effects referable to agents of igneous origin. The discovery, therefore, of evidence which proves that hydrothermal metamorphism has affected sands and sandy shales to the extent of changing them to quartzites is a fact of considerable interest and importance.²

The quartzites occur at Silver City,³ the eastern end of a long east-

¹ Manuscript received by the Secretary of the Society March 15, 1917.

² The metamorphic rocks were noted long ago by Hay and Mudge, and, as subsequently will be shown, the latter gave the correct explanation of the cause (see Trans. Kans. Acad. Sci., vols. vii and viii, 1881 and 1882).

³ Silver City received its name from the supposed occurrence of silver there, and throughout the area in the map within the heavy line there are numerous old prospect pits, some of which are said to have attained depths exceeding 100 feet. In 1879 a

west ridge in the southern part of Woodson County. This portion of the ridge forms the northeastern flank of a small anticline which for convenience may be given the name of the locality.

FIGURE 1.—Index Map of the Locality of Silver City

For assistance in mapping the structure and working out the geology the writer is indebted to two of his students, Messrs. Milburn Stryker and

farmer drove into Yates Center, then the largest town of the region, and exhibited a piece of shining gray rock. The local authority pronounced it silver ore, and when the farmer stated that an entire hill of the substance existed a few miles to the south the exodus began, and within 24 hours the towns of Yates Center and Neosho Falls, the two important towns of the region at that time, are said to have been deserted by nearly the whole of their male population and a town of shacks and tents had been started on the hill of the supposed silver ore, and there soon followed all the accompaniments of a boom mining camp. There was intense and feverish activity until an assay of some of the "silver ore" was received from Kansas City, and it was learned that the supposed ore was merely worthless quartz. The miners "folded their tents and departed" and Silver City became a memory and a pasture, with nothing remaining to mark its one-time existence save the old prospect pits (compiled from newspaper reports).

W. L. Ainsworth. The work was done in the interest of the Fredonia Gas Company, through whose courtesy publication is permitted. In the preparation of the article the writer had the advantage of suggestion and criticism from Professors C. K. Leith and A. N. Winchell.

GEOLOGY OF THE SILVER CITY AREA

THE LOCAL SECTION

Before considering in detail the altered rocks it is thought best to give a brief description of the geology of the area surrounding Silver City ridge, in order to define the formations and to afford data for contrasting the altered rocks with the unchanged.

The local section includes two of the great sand-shale and two of the limestone members of the Kansas Coal Measures. In describing these divisions, the lithology normal to each is given, while the variations due to alteration are left to subsequent paragraphs. Only such details are given as have a bearing on the problem.

LAWRENCE SHALES

This, the topmost division of the local section, consists of red, yellow, gray, blue, and black shales and sandstones of ferruginous colors. The division is highly cross-laminated, of variable stratification and lithology in both the horizontal and vertical sense, and is generally of crumbling texture. Generally there are many bands of shale and sand which contain mica (apparently muscovite) in great abundance. The thickness is variable, but generally exceeds 150 feet. About 50 feet remain on the east tip of Silver City ridge.

IATAN (KICKAPOO) LIMESTONE⁴

This division is one of the most easily recognized of the Kansas Coal Measures and, for a thin member, its horizontal extent is remarkable. The upper layer is a compact, very dark blue, semicrystalline limestone of fine texture and brittle fracture. The farmers describe it as flinty. It is characterized by a highly developed vertical jointing, with the joint planes meeting at oblique angles. The thickness of this layer varies between 1 and 2 feet. Below the upper layer are from 2 to 10 feet of strata of variable lithology with those of limestone composed for the most part

⁴ The name "Iatan" was applied to this limestone by Keyes, Am. Geologist, vol. 23, 1899, p. 306. Subsequently Haworth and Bennett (Kansas University Geol. Surv., vol. ix, 1908, p. 105) proposed the name of "Kickapoo." Since the former has priority, it is here used.

of the tests of *Fusulina*. Near Silver City the thickness of the whole is about 12 feet.

LE ROY SHALES

These are of a lithology and stratification equally as variable as are the Lawrence shales, but in the Silver City area they are of a lighter color; red shades are not common, while yellows predominate. Far less sand is also present and the greater portion of the division is a shale. Small flakes of mica are quite common. At the base are about 80 feet of dark blue and black shales. The division is known to be 204 feet thick on the northwestern margin of the area.

STANTON LIMESTONES

These are the lowest rocks exposed in the immediate vicinity of Silver City. They are gray, rusty spotted limestones of variable thickness and are not well bedded. They are not exposed in the altered area.

THE SILVER CITY ANTICLINE

The Silver City anticline has the form of an elliptical dome with the long axis trending nearly east and west. Due to lack of data, the eastern margin is perhaps not quite correctly mapped. The other portions of the structure are believed to be fairly accurately drawn. With the exception of the northeastern margin, all margins are fairly regular. The former is comparatively irregular, and it is clear that in the development of the anticline considerable crushing and fracturing occurred there. There is no evidence of faulting. On the contrary, the outcrops of the strata show the improbability of the presence of a fault with a throw of more than 4 or 5 feet. The anticline is expressed in the topography as a basin.

DETAILED GEOLOGY OF SILVER CITY RIDGE

The Lawrence shales and sandstones, which on the adjacent ridges as well as on the north side of Silver City ridge have the characteristics typical of the division, consist throughout the area in the map within the heavy line of very hard, compact quartzites, which locally contain small cavities lined with crystals of quartz and, more rarely, of pyrite. There is no trace of the red colors which are characteristic of the rocks of this division in surrounding areas, but instead there are shining gray and greenish shades. In the sunlight the quartzite sparkles brilliantly, and it was probably this characteristic which led to its being mistaken for silver ore. Examination of the rock in thin-sections proves it to be com-

posed of grains of pure quartz sand cemented with quartz with a variable proportion of chlorite in those portions which are of greenish shades. Beds of the latter shades are generally finely laminated and originally probably contained some argillaceous and ferruginous material. The lamination is original, being due to conditions of sedimentation and not to parallel development of minerals induced by the pressure.

The upper layer of the Iatan limestone at the point A is of the normal character and continues so to the point B. Just east of B the cracks in the limestone are filled with hard black chert, which within a distance of

FIGURE 2.—The Silver City Anticline

Elevations are based on an assumed elevation of 1,000 feet. The area within the heavy line is underlain by the altered rocks

a hundred or so feet to the east completely takes the place of the limestone, the change being gradual. The strata are well exposed, so that no mistake of identity is possible. The change is also accompanied by a thickening of the bed, an increasing percentage of impurity therein, and the assumption of a greenish shade. Fossils are visible in the replaced rock. A thin-section made from the chert filling the cracks in the limestone shows nothing other than would be expected in such a rock. A section from the equivalent of the limestone east of B shows the development of a considerable amount of chlorite. At C there is no trace of the limestone, but what appears to be its stratigraphic position is held by a

brecciated, dark green, very earthy chert, which has a thickness of about 5 feet. The bed could not be traced from B to C, as the interval is covered; but the character of the rock, except for the brecciation, is the same, and there seems little doubt but that the correlation is correct. A thin-section made from the breccia at C showed exactly the same mineral constituents as the rock in the place where brecciation had not occurred. The cherty fragments show no wear whatever and are generally, but not everywhere, well cemented together, the cement being of a lighter shade of green, but still dark. Many of the fragments have their peripheral portions nearly white, or at least of a lighter shade than are the centers, and in the cases of many of the smaller pieces the change of color extends to the center. At D typical Iatan limestone occurs, while at E the degree of brecciation is greater than was seen elsewhere, although, as in the previous instance, it is not certain that the breccia is the equivalent of the limestone, although it holds what appears to be the position belonging to the latter, and in it was found a marine fossil which could not have come from either of the shale divisions, since they are without marine fossils in this region. Mineralogically, the breccia at E is somewhat different from what it is at C, as is shown by the notes which Professor Winchell kindly made for the writer. At G typical Iatan limestone is exposed, and traced northwesterly it shows no change. At F the alteration appears to be merely initial, while east of F there are no exposures in which any evidence of alteration is visible. In none of the exposures of this division was there observed any parallel arrangement of minerals or rock fragments.

The Le Roy shales underlying Silver City ridge are finely laminated, well cemented, fine-grained quartzites of a gray to greenish color. There are no yellows or reds, nor is there any orientation of constituents which is referable to dynamic processes. In the deepest shaft which was dug Professor Mudge states⁵ that the sandstones "assumed the form of bluish green cherts" which "is traversed by veins of white quartz." Hay considered this chert to be a "true igneous rock,"⁶ a view not supported by Mudge. The shafts are now largely filled up, but much of the debris which was thrown from them remains scattered over the ridge, and this debris contains no igneous rocks.

Near the top of the south side of the ridge are several very excellent cold-water springs. Since they occur on that side of the ridge from which the strata are inclined, it is rather difficult to explain their presence except on the assumption that the water rises along fractures.

⁵ Mudge: Trans. Kansas Acad. Sci., vol. vii, 1881, p. 12.

⁶ Robert Hay: Ibidem, vol. viii, 1882, p. 17.

FIGURE 3.—*The Silver City Breccia (natural size)*

The large fragments are composed of chert and chlorite with rare hornblende and epidote. The matrix consists chiefly of acicular dark green hornblende.

The notes which follow were kindly prepared for the writer by Prof. A. N. Winchell. Specimen number 4 came from the brecciated equivalent of the Iatan limestone of locality E, while number 7 was derived from an exposure of the Le Roy shales near the point D.

"Number 4. In hand sample the rock is composed of angular fragments of dark green color which have been altered in part (by surface waters?) to a white mineral. These fragments are held together by a heterogeneous cement which includes some material probably detrital in origin and some which has crystallized from solution. The latter is chiefly acicular dark green hornblende in rosettes.

"In thin-section the dark green color of the fragments is found to be due to abundant well crystallized lamellæ and needles of dark green chlorite, while the white mineral is chiefly opal or chert. There is also some rare hornblende and rather common grains of epidote which form granular aggregates in some places. The epidote is not only pleochroic, but also varies in color in different crystals from golden yellow to brown and brownish gray. It is biaxial, has high relief and extreme birefringence, indicating an epidote rich in iron.

"The probable history of the rock is as follows: A siliceous limestone was broken by local movements into abundant fragments of all sizes. The broken zone furnished a ready channel of flow for carbonated waters which dissolved and removed the iron and carbonates from the smaller fragments and from the outer zone of the larger fragments, thus increasing the porosity of the mass. At a later date the same channels served as paths of escape for hot solutions coming from greater depths, and these removed any remaining carbonate and at the same time caused the growth of chlorite, epidote, and hornblende. Such solutions were probably wholly or partly of igneous origin.

"Number 7. In hand sample the rock has a light grayish green color with very minute brightly reflecting white scales. It weathers to a darker brownish green color.

"In thin-section the texture is intermediate between that of a pelite and that of a psammite, the pelite ground-mass being plentifully sprinkled with rounded grains of feldspar. The chief constituents are orthoclase and finely divided argillaceous material, including chlorite, sericite, and kaolin. There are rare crystals and fragments of zircon, apatite, and magnetite. Recrystallization has developed a mineral of hazy grayish brown to brownish green color having high relief and strong birefringence; it is biaxial and negative with a large optic angle and a granular habit; it is almost certainly epidote."

Two wells have been drilled on the Silver City anticline, the places being indicated on the map as 1 and 2. Each reached the Mississippian limestone at depths a little greater than 1,300 feet. In the well of location 1 the drillers constantly complained that they were not finding rocks with which they were familiar and which they had found in the wells of the vicinity. When the well of location 1 proved a failure, location 2 was chosen in order to get as far as possible from the altered rock of Silver City ridge. In this well the rocks did not materially differ from those of

well number 1, except that the abnormal rocks were met at a slightly greater depth.

Neither the logs of the wells nor the samples therefrom showed igneous rocks, but many horizons of slate were indicated. The rocks which drillers indicate as slate, however, are generally hard shales, and such is probably the case in these wells, as the logs also show shales lying between slates. In each well rocks were encountered which the drillers identified as mica. These proved to be merely fine-grained sandy shales carrying large quantities of hydrated mica. Black limestones were indicated in the logs. These were found to contain no calcium carbonate, but to be hardened chloritized material containing hydrated mica. They appear to have been black shales. Both the micaceous substances and the black rocks have a distinctly soapy feel.

The data given by the well logs make it appear quite probable that alteration has affected the sediments beneath the anticline to a considerable extent, and that the alteration becomes deeper with distance from the Silver City ridge. In itself, however, the evidence of the wells is of little value; but taken in connection with the actual fact of alteration it is corroborative.

SUMMARY OF THE DATA

(1) Silver City ridge lies on the northeastern flank of a comparatively high anticline, and on this flank there has been rather decided local deformation of the strata.

(2) In a narrow zone on the northeastern flank of the anticline the Lawrence shales, which elsewhere are poorly cemented sands and shales of varied colors, are compact, hard quartzites of a gray or greenish color, the green being due to the development of variable proportions of chlorite.

(3) The Iatan limestone, which elsewhere than on the south face of Silver City ridge is a compact splintery limestone in its upper division, is there replaced by a dark green earthy chert, or a breccia from the same, with the chert making its first appearance in a purer and harder form, as fillings in the cracks of the limestone, while the matrix of the breccia and, to a lesser degree, the fragments contain hornblende, epidote, and chlorite which crystallized from solution at a time subsequent to the brecciation.

(4) The Le Roy shales, which in the areas surrounding Silver City ridge are poorly cemented yellow and gray sandy shales, on the south side of the ridge are fine-grained, well laminated, firmly cemented gray and light green quartzites.

(5) Not one of the altered rocks has had developed any parallel orientation of its minerals or any structure which can be referred to dynamic metamorphism.

CAUSES OF THE ALTERATION

It is quite possible for quartzite to be developed through processes of ordinary cementation of sedimentary rocks. No special conditions are required for the development of chert and flint, since these are known to be commonly formed in the zone of fracture in the presence of cold water. The occurrence of these rocks, therefore, requires nothing other than ordinary sedimentary and ground-water conditions. No known process of sedimentation, however, can account for the development of the hornblende and its origin must be referred to some other process, and as the chert and quartzite appear to be genetically related to the hornblende, it is inferred that all three, together with the chlorite and the epidote, originated in the same manner.

It has been pointed out that there is no parallel development of minerals in any of the rocks, so that pressure metamorphism as a cause of the alteration is eliminated. Metamorphism of the contact type appears to be out of question, as no igneous rocks have been recognized in the strata altered or contiguous thereto. Furthermore, the alteration is quite unlike that generally associated with heat metamorphism. This leaves hydrothermal metamorphism as the only possible cause of the alteration, and everything which was observed is in harmony with the view that the quartzites and associated rocks were developed through the circulation of hot waters. Mudge explained the metamorphism in the same manner.⁷ He, however, failed to observe the hornblende, epidote, and chlorite.

The sequence of events in the Silver City area is believed to have been something as follows: Prior to the deformation of the strata a quite normal lithology of the three divisions known to have been modified obtained in the Silver City area. Deformation locally brecciated the upper Iatan limestone—the only brittle member of the known modified rocks—and opened cracks to greater depths. Circulating waters which were probably of surface origin removed the soluble constituents from the fragments of the limestone, leaving the clay and silica with perhaps some increase of the latter. Later, hot solutions coming from great depths circulated through the fractured and porous zones and ultimately filled the pores and cracks with chert, hornblende, chlorite, and epidote and cemented the fragments together with substances of the same character. The sand-

⁷ Mudge: Loc. cited, p. 12.

stones and shales were also firmly cemented through the precipitation of material from these hot solutions, the cementation being accompanied by the development of chlorite. Nothing is known as to the depth from which the hot water came or its method of origin.

RELATION OF THE ALTERED ROCKS TO THE LEAD AND ZINC DEPOSITS OF
SOUTHEASTERN KANSAS, THE ROSE BOULDERS, AND THE GRANITES
REPORTED FROM THE DEEP WELLS OF CENTRAL KANSAS

The recognition of the fact that Pennsylvanian strata of eastern Kansas have been altered by hydrothermal processes raises three questions. They are as follows: (*a*) Is there any relation between the metamorphism which has occurred at Silver City and the lead and zinc ores which are found in the near vicinity?⁸ (*b*) Does the fact of alteration have any bearing on the origin of the granite porphyry boulders which occur in the vicinity of Rose, only about 6 miles to the north?⁹ (*c*) Is there any connection between the granite reported in deep wells of central Kansas and the metamorphism at Silver City? These three questions will be considered in detail.

(*a*) No lead or zinc minerals have ever been noted in the altered rocks of Silver City, so that it is quite unlikely that the formation of the quartzites and related rocks are related to the development of the lead and zinc deposits.

(*b*) While studying the boulders at Rose, the writer tested as one hypothesis of origin the possibility that they might have been derived from a dike, sheet, or flow. It was pointed out that a small quartz vein had been observed a distance of a quarter of a mile from the boulders, and it was stated that the alignment of the greater portion of the material is in harmony with the idea that the boulders are parts of an extrusion or intrusion; but the coarse-grained character of the material, the absence of metamorphism and contiguous deformation caused the hypothesis to be rejected. Since that paper was written the writer's attention has been called to the fact that three wells have been drilled on the southeastern margin of the area over which the boulders are distributed, each reaching the Mississippian limestone. No alteration of strata is reported to have been found in the wells, nor was any igneous rock encountered. One of the wells is said to have produced gas for several years. The evidence of the wells supports the view that there is no intrusion or extrusion present

⁸ Haworth: Kansas Univ. Geol. Surv., vol. viii, 1904, p. 43.

⁹ Twenhofel: Am. Jour. Sci., 1917, p. 363.

at Rose, and, if this view be correct, it follows that the boulders bear no relation to the metamorphism observed at Silver City.

(*c*) Facts which have lately come to the writer from many sources indicate that in central Kansas real granitic masses in place are being reached by the drill. All the evidence, however, which the writer has received indicates that the granites are older than the overlying Pennsylvanian strata. If such be correct, it follows that they bear no relation to the metamorphism observed at Silver City. If they be intrusive in the Pennsylvanian strata, there may be some connection.

Geological Society of America Bulletin

The Silver City quartzites: A Kansas metamorphic area

W. H. TWENHOFEL

Geological Society of America Bulletin 1917;28, no. 1;419-430
doi: 10.1130/GSAB-28-419

Email alerting services

click
www.gsapubs.org/cgi/alerts to
receive free e-mail alerts when
new articles cite this article

Subscribe

click
www.gsapubs.org/subscriptions/ to subscribe to Geological
Society of America Bulletin

Permission request

click
<http://www.geosociety.org/pubs/copyrt.htm#gsa> to contact
GSA

Copyright not claimed on content prepared wholly by U.S. government employees within scope of their employment. Individual scientists are hereby granted permission, without fees or further requests to GSA, to use a single figure, a single table, and/or a brief paragraph of text in subsequent works and to make unlimited copies of items in GSA's journals for noncommercial use in classrooms to further education and science. This file may not be posted to any Web site, but authors may post the abstracts only of their articles on their own or their organization's Web site providing the posting includes a reference to the article's full citation. GSA provides this and other forums for the presentation of diverse opinions and positions by scientists worldwide, regardless of their race, citizenship, gender, religion, or political viewpoint. Opinions presented in this publication do not reflect official positions of the Society.

Notes