Geology of the Hill City Quadrangle Pennington County South Dakota—A Preliminary Report

GEOLOGICAL SURVEY BULLETIN 1271-B

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By JAMES C. RATTÉ *and* RUSSELL G. WAYLAND

CONTRIBUTIONS TO GENERAL GEOLOGY

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General geology of a deformed area that is underlain by Precambrian phyllites and schists and is intruded by granite and pegmatites in the central Black Hills of South Dakota

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GEOLOGY OF THE HILL CITY QUADRANGLE PENNINGTON COUNTY, SOUTH DAKOTA— A PRELIMINARY REPORT

By JAMES C. RATTÉ and RUSSELL G. WAYLAND

ABSTRACT

The Hill City quadrangle, in the central Black Hills, South Dakota, is underlain by Precambrian phyllites and schist, which are intruded by granite and attendant zoned and unzoned pegmatites on the northwest flank of the Harney Peak dome. Adjacent to the dome, the schists are metamorphosed to sillimanite grade. The rocks are deformed by faulting and by two major and one minor set of folds, Gold, spodumene, tin, mica, beryl, feldspar, and tungsten have been mined in the quadrangle.

INTRODUCTION

The geologic map of the Hill City quadrangle (pl. 1) is part of a study by the U.S. Geological Survey of the pegmatites of the central Black Hills and their geologic setting. Early phases of this work concerned detailed pegmatite investigations, most of which have already been reported. Present work consists primarily of detailed regional mapping of quardrangles in the pegmatite area. The geologic map of the Fourmile quadrangle, west of Custer, was the first completed, and it was published as part of a comprehensive study of the geology and pegmatites of that area (Redden, 1963). A similar study of the Berne quadrangle was made by Redden (1968).

Previous geologic studies in the Hill City area include reconnaissance mapping by Darton and Paige (1925), a thesis on the Hill City area (Janosky, 1949), and numerous descriptions of mines and prospects. The structure and origin of the Harney Peak dome and of other Precambrian granite domes in the Black Hills were described by Runner (1943) and by Balk (1931).

GEOLOGIC SETTING

The Hill City quadrangle is in the central part of the Precambrian core of the Black Hills uplift. The Precambrian rocks within the quadrangle are chiefly pelitic phyllites and schists, and metagraywackes, which are intruded by part of a small batholithic mass of pegmatitic granite, the Harney Peak Granite. The Hill City quadrangle is on the northwest flank of the Harney Peak dome, which was formed by the intrusion of this batholith, and contains about 2 square miles of Harney Peak Granite in its southeast corner. Additional sheets of pegmatitic granite, including some zoned pegmatites, form satellitic intrusive bodies throughout the south half of the quadrangle, but become less abundant away from the main granite body. The age of the Harney Peak Granite, as indicated by isotopic ages of its associated pegmatites, is about 1,600 m.y. (million years) (Davis and others, 1955, p. 146–147; Kulp and others, 1956).

STRATIGRAPHY

The metasedimentary rocks in the Hill City quadrangle are divided into two formations: the Oreville Formation, defined herein, and the Bugtown Formation, defined by Redden (1963).

OREVILLE FORMATION

The Oreville Formation is named for the Oreville rail siding in the Custer quadrangle 0.6 mile south of the Hill City quadrangle on U.S. Highway 16. The type locality is along the north bank of Spring Creek west of Oreville, where the two fine-grained pelitic facies of the formation are well represented. They are:

1. Biotite facies: laminated quartz-biotite-garnet schist containing characteristic iron-stained garnet-rich beds generally a few tenths of an inch thick; locally grades into somewhat graphitic rocks.
2. Muscovite facies: streaked quartz-muscovite-biotite-garnet schist having variable bedding characteristics which range from thinly laminated (pinstripe) to rather thick massive beds and rocks without distinct bedding. Abundant tiny magnetite octahedra and pyrite metacrysts or their hematite pseudomorphs are locally common in this facies.

Rocks of the two pelitic facies are commonly interlayered and have been mapped insofar as practicable according to the dominant facies present.

The Oreville Formation in the Hill City quadrangle also contains a psammite facies consisting mainly of massive to foliated metagraywacke and quartz schist, which grades into micaceous quartz schist and is interlayered in many places with the two pelitic facies. This third facies is best developed in the Zimmer Ridge Member of the formation, a metagraywacke unit that is named here for a belt of outcrops nearly a mile wide along Zimmer Ridge, which is near the southwest corner of the quadrangle and is designated the type locality. The member originally was 0 to 1,000 feet thick, but it commonly is greatly overthickened by folding, as along Zimmer Ridge, or is stretched out to form detached masses. It pinches out along the east flank of the Union Hill anticline, probably mainly through facies change but partly as a result of deformation. Metagraywacke in both the Oreville and Bugtown Formations forms large and prominent outcrops that underlie many of the topographic ridges in the quadrangle, and it is especially useful in establishing stratigraphy and structure during geologic mapping.

The lower contact of the Oreville is not exposed in the Hill City quadrangle, and thus the formation may contain an additional thickness of rocks not described here. At the upper contact, the Oreville consists of micaceous schist, whereas the bottom of the Bugtown Formation has massive metagraywacke beds. Sedimentary structures, including graded bedding and load casts, in Bugtown metagraywacke near the north edge of the quadrangle east of Marshall Gulch confirm that the Oreville is older than the Bugtown. Complex folding and lack of information about the lower part of the Oreville make it difficult to estimate the thickness of the formation; probably it is nowhere less than 2,000 feet thick, and its maximum may be 10,000 feet.

The Oreville Formation contains minor but distinctive calc-silicate beds and concretions, which are more abundant interlayered with massive-bedded rocks than with thin-bedded ones. The beds are ordinarily only a few inches to a foot thick and are continuous for only a few tens of feet at most. In places they have been squeezed and separated into ellipsoidal masses or boudins, although some ellipsoids probably were calcareous concretions as described by Runner and Hamilton (1934) and Redden (1963). Quartz, calcic plagioclase, amphibole, pyroxene, calcite, sphene, and apatite are the principal minerals in these rocks (Runner and Hamilton, 1934).

Two main varieties of amphibole rock, in beds generally less than a foot thick, are sparsely distributed in the more micaceous facies of the Oreville. One variety is massive to gneissic, and the rock consist largely of coarse blades of greenish-black amphibole with quartz. In the northeast part of the quadrangle, the amphibole in such beds is partly or completely replaced by chlorite. The other variety is a quartzose rock having scattered streaks and clusters of radiating amphibole crystals; it commonly is highly weathered, iron stained, and porous. Actinolite is the principal amphibole indicated by optical properties in thin sections of both varieties, but cummingtonite may be present in some places. Garnet is comon in all the amphibole rocks, but plagioclase has not been detected. The constituents of the amphiboles probably were derived from carbonate minerals in the original sediments, but the quartz probably recrystallized from chert or from clastic material.

The composition of rocks included in the Oreville Formation is shown by eight chemical analyses in table 1; the sample localities are designated on plate 1. Rocks belonging to the dominant biotite facies

TABLE 1.—*Chemical analyses, in percent, of metasedimentary rocks of the Oreville Formation*

[Analyses 1, 2, 3, 5, 6, 8 by Ellen Daniels; analyses 4, 7 by George Riddle. Carbon determined pyrolitically by Irving Frost. ----, not determined. Sample types: analyses 1, 4, 5, 6, 7, and 8 are 20- to 40-lb composite samples; analysis 2 is a 20-inch-long channel sample across 60–80 thin beds, approximately 1 lb; analysis 3 is a selected sample, approximately 5 lbs.]

Facies	Biotite						Muscovite	Psammite
Analysis No.	1	2	3	4	5	6	7	8
Field No.	HC-63-3A	HC-63-6A	HC-63-7A	H-64-208A	HC-63-4A	HC-63-5A	H-64-70A	HC-63-1A
Map location	D-6	D-6	B-4	B-1	C-5	E-2	B-7	A-7
SiO_2	57.93	58.22	59.35	62.09	59.98	60.12	62.33	72.67
Al_2O_3	14.77	15.13	10.30	17.42	17.99	16.38	18.60	12.79
Fe_2O_3	3.84	3.91	8.53	4.02	1.06	1.44	.90	.49
FeO	8.28	7.90	8.87	3.17	7.11	7.60	5.40	3.02
MgO	2.86	2.92	1.62	2.18	2.78	2.99	2.38	1.54
CaO	1.32	1.23	1.34	.39	1.07	1.31	.70	1.48
Na_2O	1.61	1.52	.05	1.93	2.45	2.08	1.49	2.49
K_2O	3.17	3.44	1.47	4.30	3.87	3.79	4.60	3.88
H_2O+	2.20	2.29	2.01	2.56	1.84	1.82	2.23	.63
H_2O-	.44	.36	.39	.11	.05	.12	.09	.04
TiO_2	.56	.57	.34	.69	.68	.62	.67	.48
P_2O_5	.17	.14	.46	.14	.12	.13	.12	.13
MnO	1.29	1.18	3.22	.49	.60	1.14	.12	.06
CO_2	.01	.01	.03	.01	.00	.01	.02	.03
SO_3	.94	.77	.01	----	----	.00	----	----
Cl	.01	.01	.01	.00	.00	.03	.00	.00
F	.12	.13	.09	.14	.12	.14	.13	.06
S	.02	.02	.03	----	----	.01	----	----
C	.39	.38	1.95	----	----	.35	----	----
Subtotal	99.93	100.13	100.07	99.64	99.72	100.08	99.78	99.79
Less O	.06	.06	.06	.06	.05	.07	.05	.03
Total	99.87	100.07	100.01	99.58	99.67	100.01	99.73	99.76

1, 2. Thin-bedded quartz-biotite-garnet schist without appreciable muscovite. Mapped with muscovite facies at this locality.
3. 1- to 2-inch iron-stained garnet-rich bed in thin-bedded quartz-biotite-garnet schist.
4. Light-green quartz-mica phyllite containing tiny pink garnets and magnetite octahedra. Garnet beds lacking or smaller and less abundant than in the biotite facies. Muscovite comparable in abundance to biotite.
5. Quartz-mica-garnet phyllite, lacking conspicuous garnet-rich beds.
6. Gray quartz-biotite-chlorite-garnet phyllite with some thin garnet beds.
7. Light-colored quartz-mica-garnet-chlorite schist.
8. Metagraywacke, Zimmer Ridge Member.

are represented by analyses 1 to 6. Light-colored quartz-muscovite-biotite-garnet schist of the muscovite facies of the Oreville is represented by analysis 7 and metagraywacke of the Zimmer Ridge Member, by analysis 8. Except for the metagraywacke and the garnet-rich bed, these rocks have compositions in the range of shales, although they are commonly somewhat richer in total iron and manganese oxides than the average shale cited by Pettijohn (1949). The garnet-rich bed has a total iron oxide content exceeding 17 percent, accompanied by abundant manganese oxide and carbon but only sparse alumina, soda, and potash; its composition suggests that it was originally an impure iron carbonate sediment.

BUGTOWN FORMATION

The Bugtown Formation (Redden, 1963) in the Hill City quadrangle is probably 5,000 to 10,000 feet thick. It consists mainly of massive thick-bedded metagraywacke (analysis 9, table 2) interlayered with quartz-mica schist and phyllite. Quartz-mica schist from the staurolite and sillimanite zones is represented by analyses 11 and 12, table 2. Minor rock types shown locally on plate 1 include graphitic schist and phyllite, amphibole and calc-silicate rocks, conglomerate, and grit. The graphitic unit at the north border of the quadrangle, shown between D–1 and E–2 on the geologic map, contains much graphitic and highly iron-stained rock and some calc-silicate and amphibole-rich beds, as well as thin-bedded quartz-biotite-garnet phyllite that is not unlike the typical Oreville rocks with which the unit is locally in contact across the Empire fault. The southeast end of this unit is probably the site of a facies change, the exact nature of which is not clear from the few exposures available. Two thinner units of graphitic schist have been mapped from the east side of the Hill City fault (F–4 on pl. 1) to the vicinity of the Golden Summit mine (F–7 on pl. 1). These units are particularly distinctive where the dark sooty graphitic schist contains myriad tiny tourmaline needles. Southwestward from the Golden Summit mine, at a stratigraphic position similar to that of the graphitic schist, there is a thin discontinuous unit or units consisting of coarse amphibole rock a few inches to about 1 foot thick, graphitic schist, streaked quartzite, and calc-silicate rock, which total a few tens of feet in maximum thickness. Thin calc-silicate beds and concretions like those in the Oreville Formation are interlayered with the more massive rocks of the Bugtown Formation.

Metagraywacke, quartz-mica phyllite (analysis 10, table 2), and quartz-mica schist in the northeast corner of the quadrangle seem to be in normal sequence above the Oreville rocks of the Gordon Gulch area.

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TABLE 2.—*Chemical analyses, in percent, of metasedimentary rocks of the Bugtown Formation*

[Analysis 9 by Ellen Daniels; analyses 10–12 by George Riddle. Sample type: 20- to 40-lb composite]

Analysis No	9	10	11	12
Field No	HC–63–2A	H–64–270A	H–64–352A	H–64–388A
Map location	E–5	G–1	G–7	E–10
SiO_2	72. 69	69. 99	61. 05	59. 85
Al_2O_3	13. 37	14. 41	19. 60	19. 79
Fe_2O_3	. 72	1. 16	1. 09	. 86
FeO	3. 08	3. 64	5. 69	6. 16
MgO	1. 33	1. 74	2. 46	2. 55
CaO	. 54	. 44	. 35	. 39
Na_2O	2. 08	1. 16	. 98	. 74
K_2O	3. 90	3. 85	5. 13	5. 16
H_2O+	1. 17	1. 95	2. 46	2. 87
H_2O-	. 03	. 07	. 03	. 13
TiO_2	. 49	. 70	. 73	. 69
P_2O_5	. 14	. 19	. 12	. 17
MnO	. 06	. 08	. 09	. 07
CO_2	. 01	. 02	. 01	. 02
Cl	. 01	. 01	. 00	. 00
F	. 08	. 11	. 13	. 14
Subtotal	99. 70	99. 52	99. 92	99. 59
Less O	. 03	. 05	. 05	. 06
Total	99. 67	99. 47	99. 87	99. 53

9. Metagraywacke.
10. Spotted quartz-mica phyllite.
11. Quartz-mica-staurolite-andalusite-garnet schist.
12. Quartz-mica-sillimanite-garnet schist.

However, it is not certain whether the rocks of Oreville lithology in this area correlate with the Oreville in the rest of the quadrangle. The quartz-mica schist in this area contains beds of dark-gray to black glassy quartzite, which are not present in the Bugtown schists elsewhere in the Hill City quadrangle, but are common along strike to the southeast in the Mount Rushmore quadrangle (J. J. Norton, oral commun., 1966).

HARNEY PEAK GRANITE

The main body of Harney Peak Granite in the Hill City quadrangle ranges from medium- and coarse-grained granite to pegmatite. Beyond the borders of the main mass, the rock is almost entirely pegmatite in sheets and dikes that include zoned pegmatites, as well as layered and homogeneous pegmatite (Redden, 1963, p. 235). Within the batholith are numerous remnants or screens of schist in which the structure parallels that of the country rock outside the batholith. Countless exposures show that the granite was intruded along the foliation of the metamorphic rocks and followed joints for further access across the grain of the country rock. Most of the schist screens are too small to be shown to scale on plate 1, but they probably aggregate at least 10 percent of the area mapped as granite. The main granite mass shows conspicuous textural and mineralogical layering, whose origin during the crystallization of the granite was discussed by Redden (1963, p. 229–235). The domal form of the layers throughout the batholith was described by Balk (1931).

The Harney Peak Granite is a light-gray to pink albite-muscovite-perthitic microcline granite containing notable amounts of accessory tourmaline and garnet. Chemical analyses and modes of the granite in the Harney Peak area southeast of the Hill City quadrangle were presented by Oreville (1960, p. 1485).

QUATERNARY DEPOSITS

Terrace gravels, probably of Pleistocene age, are differentiated on the geologic map from Holocene gravels and alluvium in the valley bottoms. The older terrace gravels contain a few large boulders and much material of cobble size, consisting especially of pegmatite, quartz, calc-silicate rock, quartzite, and amphibolite; the latter probably originated in upper Spring Creek, several miles west of the quadrangle. The highest observed terrace remnant is in the NE¼ sec. 12 (B–8.5 on pl. 1) about 200 feet above the adjacent stream valley. Most observed terrace remnants are along Spring Creek, but a few are along Palmer Creek.

STRUCTURE

The geologic structure in the Hill City quadrangle is the result of Precambrian folding, faulting, and igneous intrusion, modified by faulting, or at least renewed movement along old faults, during the Tertiary uplift of the Black Hills.

FOLDS

Despite the many complexities shown on the geologic map and sections, the structure in the Hill City area is dominated by two sets of tight folds. The older folds are most prominent in the north and northwest parts of the area and the younger, in the south and southeast parts. The main folds of the older system are the Lowden Mountain syncline and the Union Hill anticline, which have the north-northwest trend characteristic of most of the Precambrian rocks of the Black Hills. Near Hill City, the Union Hill anticline is disrupted by a series of very tight cross folds that cause the northeasterly grain exhibited on this part of the map. Farther south, the northeast-trending folds become the dominant structures.

A preliminary analysis of minor structures indicates that the older northwest-trending folds are overturned folds having axes that plunge gently to moderately (15°–50°) southward. Geologic sections *A–A′*, *B–B′* and *C–C′* (pl. 1) show the Lowden Mountain syncline as a tight overturned fold with a steep westward-dipping axial plane; the Union Hill anticline probably has about the same form in the northwest part of the quadrangle, where it does not show the effects of later deformation. Minor folds believed to be of this age commonly have the shape of similar folds with steeply dipping nearly isoclinal limbs that thicken in crests and troughs.

The younger northeast-trending folds southeast of the Hill City fault are represented mainly by large folds like the Bishop Mountain syncline and Summit Peak anticline, which contrast in size to the northeast-trending cross folds of the same age northwest of the fault. The younger folds are overturned and their axial planes dip as much as 60° NW. in the area north of Hill City, but southeast of the Hill City fault, on the flank of the Harney Peak dome, the folds become progressively more recumbent and their axial planes dip as little as 20° NW. The plunge of the younger folds averages 30° S. 67° W. (fig. 1), but tends to decrease close to the granite. The southwest plunge of cross folds on the overturned northeast limb of the Union Hill anticline gives an upside-down stratigraphic sequence in the cross folds, which for this reason are called antiforms and synforms.

Geologic section *E–E′* (pl. 1) is drawn across the Union Hill anticline parallel to the axes of the northeast folds so as to minimize the effect of these younger cross folds. In this section, the Union Hill anticline is shown as a broad nearly recumbent fold in contrast to the tight form and steep dip of the older folds where shown in other geologic sections. The difference in form is attributed to broad warping of the older folds during late stages of the intrusion of the Harney Peak Granite and formation of the Harney Peak dome.

Other evidence of late warping is the reversal in plunge of northeast-trending folds in several areas as the area east of Zimmer Ridge and the areas northeast of Hill City on Humbolt Mountain, between Ford Mountain and Storm Hill, and at the northeast end of the Summit Peak anticline. Small-scale warps with wavelengths of several feet and north- to northwest-trending gently plunging axes are readily observed in several roadcuts in the southwest part of the quadrangle, where they commonly are associated with quartz and pegmatite intrusions.

The structure is only imperfectly known in the region of the Palmer Creek syncline. The amphibole rock and metagraywacke appear to be repeated on two sides of a fold, and thus call for a syn-

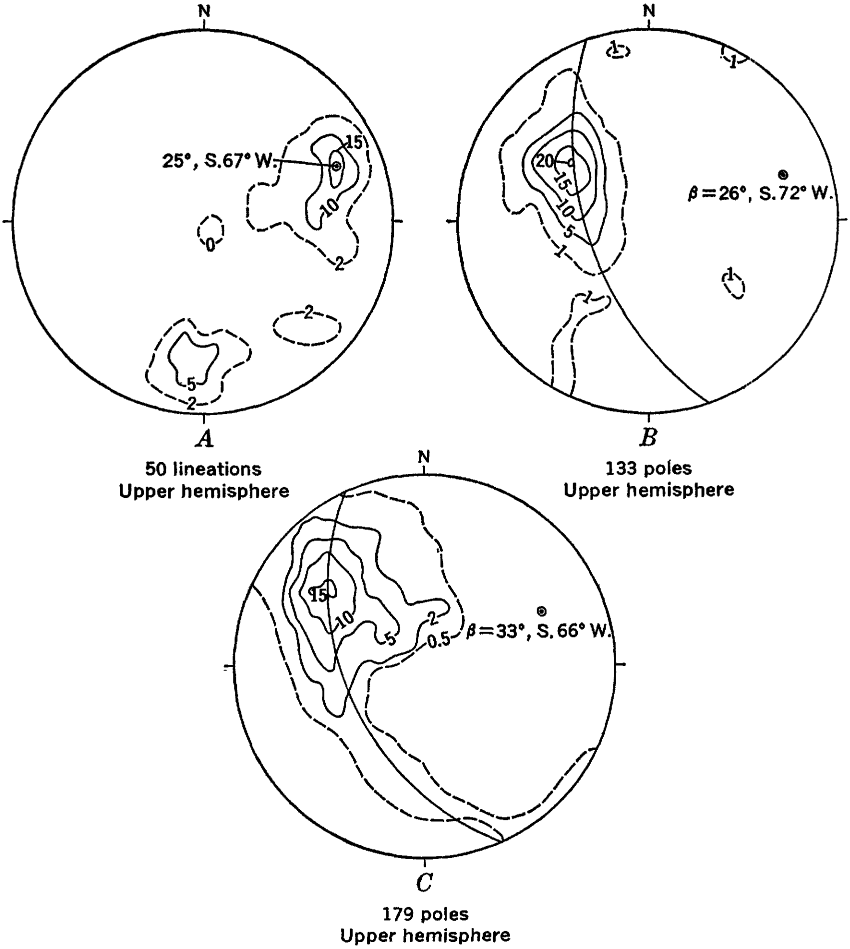

FIGURE 1.—Structural diagrams in area of northeast-trending cross folds. Contours in percentage per 1 percent area. *A*, Fold axes and other lineations, secs. 19, 20, and 30, T. 1 S., R. 5 E. *B*, Poles to bedding and foliation, secs. 19, 20, and 30, T. 1 S., R. 5 E. *C*, Poles to bedding and foliation, secs. 1–3 and 10–15, T. 2 S., R. 4 E.

cline as shown in section *D–D′* (pl. 1). Otherwise, a seemingly implausible thickness of rock is required to be overturned on the flank of the dome.

Folds intermediate in age between the older and younger major folds are the most abundant folds in the northwest and northeast parts of the quadrangle. They are restricted to folds of hand-specimen or outcrop size, and thus do not affect the map pattern appreciably.

Typically, these folds trend northward to northwestward like the older folds, but some trend northeastward. The latter are well exposed in outcrops along the north side of U.S. Highway 16, at the east edge of the quadrangle. Steep plunges, 50° to 90°, identify these intermediate-age folds. They can be seen to deform minor folds of the older low-to-moderately-plunging set in the Burnt Fork area (B3–4 on pl. 1) but are not known to deform the apparently younger northeast-trending folds.

FAULTS

Structural discontinuities evident in several places on plate 1 indicate the existence of faults having sizable displacement. Of these, the most noticeable from the map pattern is the Empire fault, which separates northwestward striking units in the northeast corner of the quadrangle from northeastward striking units to the south. Similarly, south of Hill City, the Oreville Formation in the core of the Union Hill anticline is truncated by northeastward striking units on the east side of the Hill City fault. However, direct evidence of faulting in the form of exposed fault breccia and slip surfaces is rare in the Hill City quadrangle, except for numerous small limonitic breccia zones, which generally parallel bedding or foliation and show little or no displacement. The direction and magnitude of displacement of most of the faults shown on plate 1 are uncertain, but the probable relative movement of the faults is shown on the map and sections.

Important north- to northeast-trending faults are the Burnt Fork, Hill City, and Rabbit Gulch faults and the Golden Slipper breccia zone. The Burnt Fork fault is a westward-dipping limonitic shear zone as much as 8 feet wide as exposed in prospect pits between the Gold Mountain mine and Newton Fork. It offsets both limbs of the Lowden Mountain syncline. The Hill City fault cuts diagonally across the center of the quadrangle, and it, or a related break, crops out west of U.S. Highway 16 (B–8 on pl. 1) where about 6 inches of crushed rock and slickensided gouge is present on a mullioned surface that dips 45° northwestward in a zone of intensely folded rocks. The mullions plunge about 32° southwestward. The mapped location of the Rabbit Gulch fault is based largely on a reentrant of micaceous schists, which intervenes between two ridges of massive metagraywacke, and a few pieces of slickensided limonitic breccia float north of Sunday Gulch. This fault is on trend with the Golden Slipper silicified breccia zone to the northeast.

A strong topographic lineament, conspicuous on aerial photographs, in the Harney Peak Granite is shown along the northwest side of Elkhorn Mountain (F–10 to G–8 on pl. 1). The lineament is coincident to the northeast with what Norton (1960) mapped as the trend of the

Empire fault, as named in this report. It remains to be shown that the Elkhorn Mountain lineament is the trace of a fault that actually displaces the Harney Peak Granite.

The Golden Slipper breccia zone is well exposed both north and south of U.S. Highway 16 near the east edge of the quadrangle, where it is 100 to 250 feet wide and is bordered on the west by a silicified zone as much as 300 feet wide. The breccia consists mainly of angular blocks that attain dimensions of about 1 foot and are separated by limonite-cemented fines, which form a boxwork pattern in relief. The zone splits into two northward-diverging zones south of the Empire mine; one zone continues toward the Golden Slipper shaft and the other goes through the Forest City workings of the Empire mine, both in the Mount Rushmore quadrangle. Whether, or how much, the breccia zones offset the northwest-trending faults cannot be demonstrated from existing outcrops at the Empire mine. The Golden Slipper and Forest City quartz veins were described by Allsman (1940) as striking N. 30° W. and dipping steeply southwest with a fault lying between the veins. The fault between the veins is probably the northeast offshoot of the Golden Slipper breccia zone.

The chief northwest-trending faults in the northeast part of the quadrangle are the Sheridan, Keystone, and Empire faults. The Sheridan and Keystone faults are extensions of major faults for which the main evidence is in the Mount Rushmore quadrangle to the east (J. J. Norton, oral commun., 1966). The Empire fault also was first defined by Norton (1960) in the Mount Rushmore quadrangle, but it is well expressed topographically and by the juxtaposition of geologic units in the Hill City quadrangle, and a slip surface is exposed near E–2 (pl. 1). This fault and the two lesser faults on either side of it extend southeastward toward an intersection with the Golden Slipper breccia zone a few hundred yards into the Mount Rushmore quadrangle. The southernmost of this group of three faults is exposed in pits on the ridge about 200 feet east of the quadrangle border as a 2-foot zone of slickensided limonitic breccia; it joins the Empire fault a short distance east of the pits.

MINOR STRUCTURES

Primary sedimentary structures that have been observed in the quadrangle include graded bedding, load casts, and current or festoon crossbeds. The prevalence of tight minor folds commonly renders these primary structures useless for determining tops of sedimentary units, but graded beds and load casts in turbidite-type sequences of beds in the Bugtown Formation yield some apparently reliable tops in the northeast part of the quadrangle (pl. 1).

Bedding is well preserved throughout much of the quadrangle and usually is accompanied in the finer grained rocks by a parallel foliation or schistosity. In addition, at least one penetrative cleavage commonly cuts the bedding at an angle. Complete transposition of bedding (Turner and Weiss, 1963, p. 94) along younger foliation planes is common. Along the flank of the Harney Peak dome, the subhorizontal schistosity is noticeably flatter than elsewhere; bedding and schistosity in this area are cut by a younger moderately to steeply dipping slip cleavage that probably is the youngest pervasive structure in the quadrangle.

Minor folds from hand-specimen to outcrop size occur throughout the quadrangle and are readily identified in thin-bedded units but are more difficult to outline in the more massive-bedded rocks. Minor fold axes, intersections of S planes, mineral alinements, and several forms of fluting, rodding, and boudinage form conspicuous lineations in all parts of the area.

METAMORPHISM

The Hill City quadrangle consists predominantly of pelitic rocks which range from phyllites in the northwest to coarse mica schists in the southeast. Biotite and garnet are present everywhere in rocks of appropriate composition. On the map the staurolite and sillimanite isograds show the approximate northernmost limit of these metamorphic index minerals and are roughly parallel to the contact between granite and schist. An almandine garnet isograd may also exist in the northern part of the quadrangle, but the information on the composition and distribution of the garnets necessary to locate such an isograd is lacking. Andalusite occurs mainly in the staurolite zone, but has been found in a few places north of the staurolite isograd. Widespread retrograde metamorphism is expressed chiefly by coarse chlorite porphyroblasts oriented crosswise to the dominant foliation and by local chloritization of staurolite and muscovitization of andalusite (?).

The isograd pattern indicates a metamorphic aureole related to the granite and pegmatite. The intensity of regional metamorphism that preceded the intrusion of granitic rocks is not precisely known, but it probably was below staurolite grade.

MINERAL DEPOSITS

Mining and prospecting activities in the quadrangle began in 1876. Many small mines have been worked at various times for gold, tin, tungsten, mica, beryl, feldspar, and spodumene. The aggregate value of mineral production is estimated at $1 to $2 million. Production records are fragmentary, but gold ranks first, probably accounting for about 50 percent of the value of minerals produced, and spodumene probably ranks second. Feldspar, beryl, and mica from pegmatites and tungsten minerals from quartz veins account for a few tens of thousands of dollars in past production. The largest mining operation in recent years was the Mateen spodumene pegmatite of the Lithium Corp. of America, but this mine was placed in standby in 1956, although a large share of the reserves reported by Page and others (1953, p. 155–156) still remains.

The most comprehensive mining effort was from 1884 to 1893 when an English firm, the Harney Peak Tin Mining, Milling and Manufacturing Co., prospected a large number of quartz veins and pegmatites for cassiterite. An estimated 120 tons of metallic tin, valued at $70,000 to $80,000 was mined, principally during the tin boom of the southern Black Hills between 1884 and 1912 (South Dakota State Planning Board, 1936). The cassiterite occurs in small pegmatite dikes or in quartz veins with muscovite selvages, most of which occur within a mile to the west and south of Hill City.

Gold was mined chiefly during 1890–1910, but sporadic activity, in part stimulated by the price increase in 1934, continued until about 1940. The gold occurs in quartz fissure veins and in mineralized shear zones in the Precambrian schists. The J.R. mine has the largest recorded production, about 12,000 ounces (Allsman, 1940). Only two other mines in the quadrangle, the Sunnyside and Golden Summit, have a recorded production of 500 ounces or more. However, about 6,000 ounces of gold has been produced from the Empire mine, just east of the quadrangle boundary (near G–5, pl. 1).

The age of gold mineralization is not known, but the fresh nature of the breccia along some limonitic shear zones, such as the Burnt Fork fault, suggests that some of the mineralization occurred in the Tertiary. Some gold veins in the Berne quadrangle, according to Redden (1968), are younger than pegmatites associated with them.

The geologic controls of the mineral deposits are as follows: The pegmatites occur in the aureole of the Harney Peak Granite, where their emplacement was controlled by bedding and foliation concordant to the batholith, and by crosscutting joints. Minable deposits of spodumene, feldspar, and mica are restricted to zoned pegmatites, but cassiterite and tungsten minerals are more common in quartz veins and small unzoned pegmatites. Gold deposits are most common in northeast- to northwest-trending quartz veins and shear zones, and their distribution shows no apparent relation to the granite. Detailed structural and lithologic controls cannot be ascertained because the principal gold mines are inaccessible.

Descriptions of individual mining properties in the Hill City area and appraisal of the mineral resources of gold and the valuable pegmatite minerals of the Black Hills, S. Dak., are given in several publications including the following: South Dakota Geological Survey (1964); U.S. Bureau of Mines (1955); Page and others (1953); Allsman (1940); and Gardner (1939).

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