DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TO ACCOMPANY MAP GQ-636

GEOLOGIC MAP OF THE BODIE MOUNTAIN QUADRANGLE, FERRY AND OKANOGAN COUNTIES, WASHINGTON

By Robert C. Pearson

Introduction

The Bodie Mountain quadrangle occupies the northwest corner of Ferry County and the northeast corner of Okanogan County, Wash.; its north edge is the International Boundary. Physiographically the quadrangle lies in the Okanogan Highlands (Pardee, 1918, p. 14). The dominant physiographic features of the quadrangle are the valley of Toroda Creek, a northerly flowing tributary of Kettle River (which crosses the northeast corner of the quadrangle), and the ridges that parallel the valley on either side and rise 2,000 to 3,000 feet from the valley floor. Although the relief is moderate, the country is not rugged but rather has the rounded subdued aspect of a glaciated terrane; the Okanogan lobe of the Cordilleran ice sheet overrode the entire area. A veneer of glacial deposits, chiefly till and glaciofluvial deposits, covers bedrock completely over large areas.

Bedrock geology

Along the east and west edges of the quadrangle are metamorphic and intrusive rocks, mostly of pre-Tertiary age. These are separated by a broad medial belt of predominantly volcanic Tertiary rocks which occupy a downfaulted block comparable in width and trend to the Republic graben lying some 5-10 miles to the east (Muessig, in press).

Along the east side of the quadrangle two series of metamorphic rocks have been intruded by several plutons of generally intermediate composition. Probably the oldest rocks in the region are the metamorphic rocks of Tenas Mary Creek which are exposed in an area of about 10 square miles along the north half of the east edge of the quadrangle. These rocks are extensively exposed in the adjoining Curlew quadrangle to the east where they have been adequately described by Parker and Calkins (1964, p. 5-24). The Tenas Mary rocks in the Bodie Mountain quadrangle are a dominantly metasedimentary sequence of the almandine amphibolite metamorphic facies. The sequence appears crudely conformable although some units pinch out to the east perhaps as a result of unconformities. Parker and Calkins (1964, p. 6) estimated a stratigraphic thickness of nearly 17,000 feet in the Curlew quadrangle; in the Bodie Mountain quadrangle only the middle part totaling about 5,500 feet is present. The Tenas Mary rocks as a whole are only gently warped, but the more incompetent beds commonly contain shallowly plunging overturned to recumbent small folds that do not extend into the adjoining competent beds. The Tenas Mary rocks are known only to be pre-Permian (Parker and Calkins, 1964, p. 23-24); in this respect, as well as in structure, lithology, and metamorphic grade, they are similar to the Shuswap terrane in southern British Columbia. (See Leech, 1962, p. 232, for recent summary and references.) In large part the Tenas Mary Creek rocks had a sedimentary parentage, but the amphibolite may have been volcanic and the origin of the granitic gneiss is not known. In concluding that the granitic gneiss is a paragneiss, Parker and Calkins were influenced by concordant lenses of undoubted paragneiss that it contains and by its concordant top; however, if the paragneiss lenses are inclusions and the top a nonconformity (Billings, 1942, p. 243) the rock could as well be an orthogneiss.

The metamorphic rocks of Tonata Creek extend south from the Tenas Mary Creek rocks as several roof remnants surrounded by intrusive rocks. The average dip is northerly, and, as no duplications were recognized, the sequence may well be approximately in normal stratigraphic position. In the northern part of the belt the rocks are mainly marble, calc-silicate rocks, quartzose calc-silicate rocks, and graphitic quartzite. In the central part, near Hardscrabble Mountain, they are mainly amphibolite, sillimanitic mica schist, and marble. To the south, near Horseshoe Mountain, calc-silicate rocks and sillimanitic mica schist predominate and amphibolite is minor. The age of the Tonata Creek rocks is uncertain though they may correlate in part with the schist unit of the metamorphic rocks of Tenas Mary Creek and hence are probably pre-Permian. They do not appear to correspond to metamorphic rocks along the west side of Bodie Mountain quadrangle. Strata equivalent to the Tonata Creek rocks are known in the southeast corner of the Curlew quadrangle (Parker and Calkins, 1964, p. 24-27).

Intrusive rocks in the southeastern part of the quadrangle form a temporal sequence of four distinct lithologic types and a fifth, the gneissic biotite granodiorite, whose relative age is only inferred. The age of the four youngest of these intrusive rocks is not known from direct evidence, but by analogy with other rocks in northeastern Washington and southern British Columbia they are probably mainly Cretaceous, and may range in age from Jurassic to early Tertiary. Porphyritic biotite granodiorite, the oldest of the four types, is part of a large pluton that extends south for many miles. Foliation in it is due to primary parallelism of magmatic minerals and to shearing. The shearing is regarded as protoclastic rather than cataclastic because the two types of planar structure appear to be parallel and in some thin sections small clusters of undeformed late magmatic(?) quartz and feldspar are surrounded by sheared granodiorite. The other three types are not sheared and are regarded as posttectonic. Biotite-hornblende quartz monzonite (granodiorite of Parker and Calkins, 1964), the third rock in the series, is also part of a large pluton that enlarges eastward and extends at least as far as the Republic graben where it is broken off cleanly by the bounding graben faults. The long narrow fault slice of the quartz monzonite that extends north and south of Toroda Creek, near its mouth, is probably equivalent.

The pre-Tertiary rocks along the west side of the quadrangle comprise three groups of metamorphic rocks and a plutonic mass intrusive into one of them. The three groups of metamorphic rocks do not come in contact with one another, but as they differ in lithology they probably are not correlative. Their age is uncertain from direct evidence, but they are similar to rocks to the west, north, and northeast that have been referred to the late Paleozoic and early Mesozoic.

In the southwest corner of the quadrangle gray phyllites occur throughout the length of the belt, and coarse mica schists occur mostly south of the southeastern part of sec. 11, T. 38 N., R. 30 E., where they commonly contain prominent staurolite and garnet. The narrow strip of graywacke and greenstone that extends north from the south edge of the mapped area ($1\frac{1}{2}$ miles east of the southwest corner) contains rocks of apparently lower metamorphic grade than rocks to the west. Thus the rhyodacite dike separating the two probably occupies a fault of considerable displacement.

In the northwestern part of the quadrangle a second group of dominantly metasedimentary rocks is exposed on Buckhorn Mountain and in a smaller area about 3 miles farther north at the International Boundary. Rocks of the latter area continue northward into British Columbia where, according to Little and Monger (1966, p. 67) they are Permian or older. The hornfelses are mostly siliceous and contain chlorite, sericite, and (or) biotite; some contain actinolite, epidote, and plagioclase. Relict silt-size detrital grains are present in all but the most pelitic and calcareous rocks. Crinoid columnals, the only fossils found in these rocks, are widespread in the marble, which is completely recrystallized. The intrusive metabasalt porphyry consists of relict pyroxene phenocrysts now largely pale-green amphibole, set in a light-green recrystallized aggregate of sodic plagioclase, epidote, amphibole, and a small amount of biotite.

Northeast of Buckhorn Mountain, at the head of Cedar Creek, several outcrop areas consist of chlorite-actinolite schist, limestone, conglomerate, and minor sandy and silty beds. These rocks differ in lithology from those 1 mile to the northwest and from those on Buckhorn Mountain. They also have been recrystallized less than the other pre-Tertiary rocks--some of the limestones have primary clastic textures and the conglomerates are little altered; the chlorite-actinolite schist, on the other hand, is completely reconstituted. D. A. Myers (written commun., 1964) established a maximum age for the conglomerate by determining that fusulinids in the pebbles are probably late Early or early middle Permian. This assemblage is similar to rocks in the Greenwood (82 E/2, east half) map area, British Columbia, considered by Little and Thorpe (1965) to be Upper Triassic.

The granodiorite body shown in the northwest corner of the map is part of a pluton that extends several miles north into British Columbia where it was called Rock Creek Granodiorite by Daly (1912, p. 392-393, 423) and was correlated with the Nelson intrusions of British Columbia by Little (1957). In the Bodie Mountain quadrangle the rock varies widely in composition and grain size and is extensively altered to saussurite, epidote, greenish-brown biotite, sericite, and chlorite. It has been sheared and in part recrystallized to phyllonite along numerous linear zones a few feet to several tens of feet wide and in irregular areas. The sheared rocks and phyllonites, which commonly contain pods of milky quartz, seem to be confined to the pluton and related satellite dikes.

The Tertiary rocks that occupy the central two-thirds of the quadrangle as a north-trending belt 6-9 miles wide are largely correlative with formations in the Republic area designated by Muessig (1962; in press) and Parker and Calkins (1964, p. 46-50) as the Eocene(?) O'Brien Creek Formation and Sanpoil Volcanics, and Oligocene and Miocene(?) Klondike Mountain Formation. Intrusive rhyodacite in the Bodie Mountain quadrangle may correlate with the Eocene(?) Scatter Creek Rhyodacite (Muessig, 1962; in press) but it is here considered as an intrusive equivalent of the Sanpoil Volcanics. The O'Brien Creek Formation and the Sanpoil Volcanics continue northward into British Columbia where they were described and named by Daly (1912. p. 394-400) the Kettle River Formation and Midway Volcanic Group respectively. The rocks of O'Brien Creek Formation and Sanpoil Volcanics differ little from those in the Republic and Curlew areas, but the Klondike Mountain Formation in the Bodie Mountain quadrangle is thicker and more extensive.

With only local exceptions the Tertiary rocks dip easterly at low to moderate angles, and hence the lowest Tertiary unit, O'Brien Creek Formation, is found only along the west margin of the Tertiary belt. Its sporadic occurrence is at least in part due to faulting; its greatest thickness in the Bodie Mountain quadrangle is along Beaver Creek where at least 2,000 feet of beds is preserved.

The massive lavas of the Sanpoil Volcanics appear to thicken from possibly less than 1,000 feet along the south edge of the quadrangle to about 8,000 feet in the northern part; much of the greater thickness may be due to undetected faulting.

The Klondike Mountain Formation ranges in thickness from a few hundred feet near the northeast corner of the quadrangle to many thousands of feet along the south edge. Waterlaid beds contain plant fossils of Oligocene age (identified by Jack A. Wolfe, written commun., 1962) similar to those in the Tom Thumb Tuff Member of the Klondike Mountain Formation near Republic (Muessig, 1962). Fossil fish from the same beds as the plants have been identified by D. H. Dunkle (written communs., 1962, 1965) as Amyzon, Trychophanes, Erismatopterus, and a salmon. The first two genera are known previously from the Florissant Lake Beds (Oligocene) of Colorado, and Erismatopterus is known only from the Green River Formation (Eocene).

The epiclastic nonvolcanic breccias at the base and within the Klondike Mountain Formation in the northeast quarter of the quadrangle are interpreted as lenses or sheets of pre-Tertiary rock debris that slid off a highland to the east. The breccias consist of two distinctive types of quartz monzonite and various low-grade metamorphic rocks typical of Permian and Triassic rocks in nearby areas. Near the east margin of the Klondike Mountain outcrop belt, mainly north of Toroda Creek, the breccias are mostly monolithologic and form crude sheets some tens of feet to more than 100 feet thick that seem to grade westward into conglomerate and fine-grained lacustrine beds. These monolithologic breccias commonly contain only small amounts of matrix or none at all between fragments, which are a few inches to a few feet across. In some of the breccias there has been considerable rotation of the fragments, whereas in others the rock appears only severely shattered. Also included in the breccias are some large unbrecciated masses. One such mass of quartz monzonite on the Kettle River valley wall opposite the mouth of Tenas Mary Creek is about 4,000 feet long and 500 feet thick and is surrounded by breccias of the same and other rocks.

In O'Connor Canyon nearly massive quartz monzonite is exposed over an area of more than a quarter square mile. It is overlain by variably brecciated and shattered quartz monzonite and metamorphic rocks, which in turn are overlain by volcanic rocks. The quartz monzonite and breccias are more than 1,000 feet thick. Although the bottom is not exposed, this mass is also concluded to be incorporated in the breccias and to be floored by Sanpoil Volcanics.

These quartz monzonite masses and associated breccias probably were derived by a rockfall or rockslide mechanism from the adjacent horst to the east. The process is obscure because of the extensive volcanic cover over the breccias, the abundant intrusive bodies cutting them, and erosion since they formed in the Oligocene. The quartz monzonite along the contact between the Tertiary and pre-Tertiary rocks is probably a remnant of rock that previously lay on the horst and is now preserved as a fault slice. None of the metamorphic rocks of Tenas Mary Creek are present in the Klondike Mountain Formation, thus it is assumed that they were covered by quartz monzonite and Permian and Triassic rocks when the breccias were formed. The Permian and Triassic rocks have been completely eroded from the horst in the vicinity of the breccias but still remain several miles to the north in British Columbia (Little and Thorpe, 1965).

Other closely associated breccias are interpreted as debris flows. They contain abundant fine matrix between subrounded to subangular clasts as much as 10 feet long; individual deposits are locally separated by a few inches of tuff.

Structure

The principal structural element in the quadrangle is the fault-bounded block of Tertiary rocks that trends northerly from about 8 miles south of the quadrangle and continues north into Canada. The older rocks on either side were foliated, lineated, folded, and faulted in pre-Tertiary time.

Attitudes of foliation of the metamorphic rocks of Tenas Mary Creek and of Tonata Creek plotted as poles on an equal-area net produce similar patterns and nearly coincident principal maxima indicating an average attitude of foliation of N. 35° E., 15° NW. Thus, the two groups were probably deformed at the same time and perhaps in their present relative position, that is, after they had been juxtaposed by the fault that separates them.

An equal-area plot of poles to foliation of porphyritic biotite granodiorite produces a strong maximum referable to an average foliation of N. 15° E., 10° W. This position is close enough to the principal maxima of the metamorphic rocks to suggest that protoclastic shearing in the granodiorite took place during folding and metamorphism of the metamorphic rocks, and if so, the granodiorite is syntectonic. Assuming the granodiorite to be late Mesozoic, the main deformation and metamorphism of the metamorphic rocks are likewise of that age.

Although most of the faulting is Tertiary in age, the fault that separates the metamorphic rocks of Tenas Mary Creek from those of Tonata Creek is cut off by the biotite hornblende quartz monzonite and hence is probably pre-Tertiary. As discussed above, it may be premetamorphic as well. The same fault separates similar rocks east of the Republic graben (secs. 16, 21, 22, T. 38 N., R. 34 E.) (Parker and Calkins, 1964). To judge by its straight trace where it crosses Tonata Creek it is locally steep, although the sinuous trace elsewhere suggests that the fault plane has been folded.

Most of the faults that cut the Tertiary rocks trend north to north-northeast and appear to be steep. The numerous faults of similar trend that cut the granitoid rocks in the southeastern part of the quadrangle are probably also Tertiary. Along the west side of the quadrangle several northerly trending faults separate the Tertiary from the pre-Tertiary rocks. The O'Brien Creek Formation in the valley of Beaver Creek continues about 500 feet west of the quadrangle where it has been faulted against pre-Tertiary rocks along a steep north-trending fault having a minimum vertical displacement of 900 feet. The east boundary of the belt of Tertiary rocks is interpreted as a fault contact throughout its length. East of Bodie Mountain the rocks along the contact are strongly brecciated. From there south, direct evidence for faulting is sparse; along this segment several three-point constructions give dips of about 20°-30° W. in line with a dip of 23° measured on a fault in an adit southeast of Manhattan Mountain. North of Bodie Mountain the fault is not exposed but its trace suggests a westward dip at low to moderate angles. Meager evidence suggests normal movement on this fault.

Mineral deposits

The principal mineralized areas are the magnetite and copper deposits on Buckhorn Mountain, the copper-tungsten prospect at Kelly Camp, the precious metal occurrences in the south-central part of the quadrangle, and the base metal occurrences 1 mile west of Cumberland Mountain. The Buckhorn Mountain deposits lie in altered limestones and hornfels along the contact with granodiorite. Magnetite has been mined from several high-grade lenses in garnet epidote skarn, and some copper-gold ore has been mined. Pyrrhotite and small amounts of chalcopyrite occur in the magnetite but are more abundant farther from the contact.

The Kelly Camp prospect on the southeast spur of Kelly Mountain is in a roof remnant of Tonata Creek metamorphic rocks at the contact with quartz monzonite, where garnet-amphibole-magnetite skarn contains a little scheelite and chalcopyrite.

In the Sheridan (Cascade) district south and west of Bodie Mountain, silver and gold have been mined from quartz veins and silicified volcanic rocks of the Klondike Mountain Formation. The Bodie mine was the largest producer, mainly of gold. The Phil Sheridan, Zala M., and American Flag mines south and west of Horseshoe Mountain have been minor producers, mostly of silver from small shoots in quartz fissure veins containing fluorite, calcite, pyrite, and chalcopyrite. Hessite, krennerite(?), and galena were identified from the Zala M. vein. The numerous silicified zones shown on the map are locally pyritic; some contain traces of silver. Production from the Sheridan district is estimated to be worth about $430,000.

On the ridge southwest of Cumberland Mountain numerous prospect pits contain small quantities of disseminated copper minerals; on the west side of the ridge small pods of lead-zinc-copper ore have been found at the Lupin Mine.

References cited

Billings, M. P., 1942, Structural geology: New York, Prentice Hall, Inc., 473 p.

Daly, R. A., 1912, Geology of the North American Cordillera at the forty-ninth parallel: Canada Geol. Survey Mem. 38, pt. 1, p. 1-546.

Leech, G. B., 1962, Some highlights of forty years of geological progress in the Canadian Cordillera: Canadian Mining Metall. Bull., v. 55, p. 228-233.

Little, H. W., 1957, Kettle River (east half), Similkameen, Kootenay, and Osoyoos districts, British Columbia: Canada Geol. Survey Prelim. Ser. Map 6-1957, scale 1:253,440.

Little, H. W., and Monger, J. W. H., 1966, Greenwood west half (82 E/2, W ½) map-area [British Columbia], in Report of activities, May to October, 1965: Canada Geol. Survey Paper 66-1, p. 67-71.

Little, H. W., and Thorpe, R. I., 1965, Greenwood (82 E/2) map-area, in Report of activities—field, 1964: Canada Geol. Survey Paper 65-1, p. 56-60.

Muessig, Siegfried, 1962, Tertiary volcanic and related rocks of the Republic area, Ferry County, Washington, in Short papers in geology, hydrology, and topography : U.S. Geol. Survey Prof. Paper 450-D, p. D56-D58.

Geology of the Republic and part of the Aeneas quadrangles, Ferry County, Washington: U.S. Geol. Survey Bull. 1216 (in press).

Pardee, J. T., 1918, Geology and mineral deposits of the Colville Indian Reservation, Washington: U.S. Geol. Survey Bull. 677, 186 p.

Parker, R. L., and Calkins, J. A., 1964, Geology of the Curlew quadrangle, Ferry County, Washington: U.S. Geol. Survey Bull. 1169, 95 p.