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GEOLOGY OF A PART OF THE VIRGINIA CITY AND ELDRIDGE QUADRANGLES, MONTANA

A summary report by

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MINERAL DEPOSITS BRANCH

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This report and accompanying illustrations are preliminary and have not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

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INTRODUCTION

Geologic mapping and the study of an area in the south central part of the Three Forks one-degree quadrangle was started in the summer of 1938 as a doctorate thesis problem and was continued during the summers of 1939-41, after which the work was interrupted by World War II. The work done before the war was accomplished with the aid of scholarship grants from the Yellowstone-Bighorn Research Association of Red Lodge, Montana. During the summer of 1947 the phosphate deposits within the area were studied as part of the phosphate exploration program of the U. S. Geological Survey. At this time five trenches were cut to expose the phosphatic shale member of the Phosphoria formation. One hundred and seven samples were collected for chemical analysis, including one suite across the full thickness of the formation. Two months were devoted to additional field work during the summer of 1948. The work during 1947 and half of that during 1948 was done with the help of Missouri River Basin funds from the Bureau of Reclamation.

The complex geology along the west flank of the Madison Range was mapped chiefly by plane table at a scale of 1:12,000. Most of the remainder of the area was mapped using 1:31,680 Forest Service grazing maps, and approximately 1:48,000 air photos were used in 1948.

No reliable topographic maps of the area were available at the time of the field work, but 1:24,000 preliminary maps are now available for most of the area. Base for the accompanying map was compiled from Forest Service grazing maps, air photos, and field information.

PREVIOUS WORK

The only previous work done in the immediate area of this study was the description by Peale (1896) of the Three Forks quadrangle, and a brief visit by Condit and Finch (1928) in 1916 during their study of the phosphate deposits of the region.

GEOGRAPHY

The nearly 300 square mile area involved in this study is triangular in shape and includes the southwest half of a rectangular area roughly 30 miles in east-west length by 18 miles in north-south width. It lies mostly between 111° 15' and 111° 45' west longitude and 45° 15' and 45° 30' north latitude, and is chiefly within the NE¼ of the Virginia City and the NW¼ of the Eldridge 30 minute quadrangles.

The principal part of the area is within the Madison Range, which is characterized by rugged mountain masses with local relief as much as 4,000 feet. The range is flanked on the west by the broad, deeply alluviated Madison Valley, which has a total relief of over 1,000 feet and, near the river at the western side, is prominently terraced. The valley is abruptly terminated at the north side of the area by a sharply rolling ridge, through which the Madison River has cut a deep canyon. Near the east end of the area the Gallatin River, whose narrow valley separates the Madison and Gallatin Ranges, flows into a deep canyon cut through a particularly rugged mountain mass. The total relief of the area is over 6,000 feet.

Most of the higher mountain masses within the area show marked effects of glaciation. Divides are notably narrow and mountain slopes are steep. Most streams flow through canyons, and their valleys contain limited deposits of alluvium and glacial debris which is being actively dissected.

The greater part of the mountain area is forested with fir, pine, and spruce. The Madison and Gallatin valley areas are typically grassland and in considerable part have been cultivated.

Railroads reach 4 different points within 10 to 35 miles of the edge of the area but would have to cross mountain divides or traverse deep, narrow canyons to approach much closer. Paved highways follow the Gallatin and Madison Rivers, and secondary gravel roads cross the valleys and locally penetrate a short distance into the mountains. However, a very minor part of the mountainous area is accessible by road of any kind, and travel is limited to foot or horseback.

STRATIGRAPHY

Pre-Cambrian rocks exposed are mostly gneisses of the Pony series, including some granitic intrusive masses. Marbles and quartzites of the Cherry Creek series have been thrust over younger formations near the south edge of the area.

The Flathead sandstone occurs at the base of the Paleozoic sequence of strata, and is overlain successively by the Wolsey shale, Meagher limestone, Park shale, Pilgrim limestone, and Dry Creek formation, all of Cambrian age and having a combined thickness of a little more than 1,000 feet. The Ordovician Bighorn dolomite, not previously mapped this far west, occurs in most of the area but wedges out northward. Its maximum thickness is nearly 100 feet, and it is overlain by the Jefferson dolomite of Devonian age, which is over 500 feet thick. The Three Forks formation, also of Devonian age, is very poorly exposed in the area and is usually covered by talus of overlying strata. It is apparently dominantly shale and thin-bedded limestone and is probably a little over 100 feet thick.

The Carboniferous strata include the Mississippian Lodgepole and Mission Canyon limestones of the Madison group, which have a maximum thickness of about 1,600 feet; the Mississippian-Pennsylvanian Amsden formation, containing a lower bright-colored shaly member and and upper carbonate member, which is nearly 300 feet thick; and the Pennsylvanian Quadrant formation, which is dominantly white sandstone and about 260 feet thick. The Permian Phosphoria formation is as much as 130 feet thick and includes quartzitic sandstone, chert, shale, and some phosphate rock.

The Triassic Dinwoody formation, composed of limestone, sandstone, and shale, is over 100 feet thick, and is overlain by the Jurassic Ellis formation, impure limestones and shales, which is over 200 feet thick and is at the top of the dominantly marine part of the stratigraphic section. The Jurassic Morrison formation, dominantly shales, is nearly 350 feet thick and is overlain by the Lower Cretaceous Kootenai formation, including about 500 feet of sandstone, shale, and limestone. The Upper Cretaceous strata preserved in the area include more than 2,000 feet of sandstones and shales that have not been completely measured and described and are therefore not subdivided into formational units.

Pleistocene glacial gravels, representing at least two periods of glaciation, veneer a considerable area within the Madison Range. The previously mapped (Peale, 1896) "Bozeman lake bed" deposits in the Madison Valley include principally alluvial sands and gravels, but fresh-water limestone occurs near the town of Ennis, and pumiceous deposits occur east and northwest of Ennis Lake. Fossils from the fresh-water limestone and a horse tooth from a gravel pit both indicate a Pleistocene age for much of the valley-fill material. Recent alluvium occurs in limited amount along many of the streams and near the west base of the Madison Range, where alluvial fans are still forming.

IGNEOUS ROCKS

Intrusive

Within the area of pre-Cambrian gneissic rocks are granitic intrusive bodies ranging in composition from quartz monzonite to gabbro. One of these was exposed by the erosion preceding the deposition of the Flathead sandstone, and is therefore of pre-Cambrian age. The largest occurs at the northwest corner of the area studied and probably was emplaced during the Laramide revolution. There are many small bodies of pegmatite, including graphic granite stringers. Most of these are probably of pre-Cambrian age. Basic dikes within the area range in texture from fine- to medium-grained, and at least one is post-Lower Cretaceous and probably post-Laramide in age.

In the central part of the Madison Range is a large area of over 50 square miles dominated by andesite-dacite porphyry sills intrusive into Upper Cretaceous strata. These sills appear to belong to three Christmas-tree laccoliths whose areas are so merged as to appear as one. The total thickness of intrusive rock in a single column is probably in excess of 1,500-2,000 feet near the centers of intrusion, and the ratio of intrusive to sedimentary rock in such a column is probably about 1 to 1. Erosion has nowhere reached the base of the intrusive zone, and the top has been removed, so the full thickness of the zone cannot be determined. Sills of similar composition and texture have been mapped outside of the main intrusive area, particularly to the northwest where they may provide a valuable clue to the relative ages of intrusion and development of structures.

Extrusive

Volcanic debris is common to the Upper Cretaceous strata within the mapped area but even more common to the upper part of the series now completely eroded from the mapped area. Rhyolite of late Tertiary or Pleistocene age occurs in a linear group of rounded masses at the north end of the Madison Valley. The rhyolite may be intrusive in part, but that now exposed was probably at or very near the surface at the time of cooling. Some is black and almost as glassy as obsidian and was worked by Indians for tools and weapons. Pumice occurs locally in the alluvium of the Madison Valley, particularly east and northwest of Ennis Lake, and some also occurs near the Gallatin River. Farther east the Gallatin Range is capped by large quantities of volcanic debris, including breccias and lavas, mostly of intermediate composition.

STRUCTURE

The dominant structure of the Madison Range is a broad, flat syncline trending west of north and having a sharply folded and faulted western flank. This syncline is abruptly terminated at the north by a large reverse fault beneath which the Paleozoic and Mesozoic strata have been dragged sharply upward. A broad belt of pre-Cambrian crystalline rocks is now exposed north of this fault, which is very likely a continuation of the Gardiner thrust occurring near the north boundary of Yellowstone Park. A large mass of compounded andesite-dacite porphyry sills has invaded the Upper Cretaceous sedimentary rocks in the heart of the range. Thus, Cretaceous strata and porphyry intrusives characterize the central synclinal area and belts of upturned Paleozoic and lower Mesozoic strata bound this area on the west and northeast.

The belt on the west is characterized by steeply dipping strata, which are locally sharply overturned, and by thrust faulting, which is most strongly developed toward the south end of the belt, where three thrusts occur one above the other. In the Shell Creek area some 2 miles north of the south end of this belt, the originally flat-lying strata east of the upturned belt were compressed, presumably between the developing thrust zone to the west and the mass of porphyry sills to the east, and a domal structure with a steep east side resulted. The top of the dome was sheared off by a minor thrust which subsequently became folded. This thrust is the lowermost of the three mentioned above, and is best exposed in the fenster or window in Shell Creek canyon. The rocks above the uppermost thrust belong to the Cherry Creek series. Many smaller structures are developed within this 12-mile belt, several of which are rather unusual and therefore of special interest. They are shown on the map but are not described in detail in this summary report. The thrusting is probably a northward continuation of a fault zone which Condit, Finch, and Pardee (1928) earlier observed in the southern part of the Madison Range and there named the "Madison fault."

The belt of strata on the northeast is less complicated structurally. It is dominated by the large Gardiner thrust fault which strikes about N. 60° W. and has been mapped over a length of 26 miles. East of the Gallatin River this fault appears to be double, with one branch entirely within the area of crystalline rocks but maintaining approximately the same strike as farther west, the main branch between crystalline and sedimentary rocks striking more nearly northwest.

Near the west end of this fault zone, where the belt of upturned strata along the west side of the syncline has been transected on the north, a tear fault developed in response to but in front of and normal to the northwest-trending Gardiner thrust fault. The western block moved southward along this tear fault and thereby caused a repetition of strata where the tear fault diagonally transected the west belt of upturned strata some 3 to 4 miles south of the north end of that belt—south of Jack Creek. The strata so repeated were subsequently folded and faulted at the time the Madison fault structures were developed. This rather complex structure is the most important in the area from the standpoint of chronology, for it conclusively shows that initial folding of the syncline, with stress from the west, was followed by faulting and folding along the Gardiner fault zone, with stress from the northeast, and that in turn was followed by renewed stress from the west and the development of the Madison fault zone.

The Shell Creek structure shows that intrusion of the andesite-dacite porphyry occurred prior to the development of the Madison fault. Other evidence suggests that it occurred at about the time the Gardiner fault and associated structures were developing.

Basin-Range type of fault-block movement probably started during middle Tertiary time and has continued intermittently to the present. It is well exemplified by the abrupt rise of the Madison Range from the east side of the Madison Valley and by the distinct scarp that is present along the base of the range between Jordan Creek near the north side of the area mapped and Reynolds Pass some 45 miles to the south. This type of structural development is probably chiefly responsible for the present topographic character of the region.

MINERAL DEPOSITS

The total mapped length of Phosphoria formation outcrop is 27 miles. Much of that was indicated on plate 12 of Bulletin 795-G (Condit, et al, 1928), but that map was based on reconnaissance work and does not show in more than a generalized manner the true position and relation of the formation to the structure.

The Phosphoria formation contains three principal lithologic units: a lower, somewhat cherty sandstone as much as 16 feet thick; a shale and chert member 20-40 feet thick—the lower part dominantly shale or mudstone that contains most of the phosphate, and the upper 2/3 or more dominantly thin-bedded chert with mudstone partings; and an upper sandstone and chert member about 75 feet thick. The formation and each of its members thins eastward, as do also the phosphate layers. The mapped area probably occurs fairly near the northeast border of the Phosphoria basin of deposition.

Three trenches were sampled on the west flank of the Madison syncline, oölitic phosphate rock occurring in these at three horizons over a 15-20 foot zone. The lowermost horizon is at the gradational contact with the underlying sandstone and is about 1 foot thick. The quality of the phosphate is poor due to the content of sandy and shaly impurities. The uppermost layer, locally double, is seldom more than a few inches thick and is likewise of rather poor quality. The middle layer occurs about 3 feet above the base of the shaly member. It has an average thickness of nearly 2 feet, maximum thickness nearly 3 feet, and an average grade of about 30 percent P_2O_5.

Each of the two trenches sampled to the east near the Gallatin River exposed two phosphatic layers. The lower layer probably correlates with the middle layer farther west. It is only 1 foot thick, however. The upper layer correlates with and is similar to the uppermost layer to the west. Both are of poor quality.

Condit, Finch, and Pardee (1928) sampled a 14-inch bed roughly midway between the east and west trench areas above referred to. They reported 70.3 percent of tricalcium phosphate, equivalent to 32.25 percent P_2O_5.

The phosphate deposits in this area are too thin to be worthy of consideration for mining. Furthermore, the structure and topography are so combined in much of the area that exploitation of even high grade deposits would be difficult, and transportation costs would be prohibitive, inasmuch as the nearest railroads are 25 to 30 miles distant from the phosphoria outcrops with rugged topography intervening.

Anthracite coal has been mined near the head of Mill Creek just south of the mapped area. This coal occurs in Upper Cretaceous strata, and its hardness is undoubtedly due to baking at the time of intrusion of nearby andesite-dacite sills. The coal is too hard for ordinary heating purposes. Coal has been prospected elsewhere in the Upper Cretaceous strata of the area but has not been mined.

A test well for oil has been drilled on an anticlinal structure south of the area here concerned, but the results are not known. The larger anticline shown on the map just east of the principal porphyry area appears to have closure. It may be too close to the general area of porphyry sills, however, to be favorable for oil.

Numerous copper prospect pits have been dug within the area, mostly along the Gardiner fault, but no production is known or likely. Silver has been reported from the west side of the Madison Range east of Ennis, but location of the discovery is no longer known. The gravel deposits in the Madison Valley are being used for road construction. No use has ever been made of the pumice in this immediate area, though some occurring farther south has been used locally as a scouring agent. Most of the pumice exposed is too impure for commercial consideration.

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