GEOLOGY OF THE

SMALL HORN CANYON, DALY'S SPUR, CEDAR CREEK, AND DELL AREAS,

SOUTHWESTERN MONTANA

Preliminary Report

By

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INTRODUCTION

During the summers of 1946 and 1947 several areas in southwestern Montana were investigated to determine the areal extent and structure of the Phosphoria and adjacent formations as well as the quality and thickness of the phosphate beds in the Phosphoria formation. This work is part of a study of the phosphate deposits of southwestern Montana which is one phase of a program by the Department of the Interior to investigate the natural resources of the Missouri River Basin. The geology of the Small Horn Canyon, Daly's Spur, and Cedar Creek areas (pl. 1), and of the Dell area (pl. 2) was mapped in as much detail as the aerial photographs permitted; the geology of some intervening areas was mapped by reconnaissance. In the area west of Daly's Spur and U. S. Highway No. 91, the geology was mapped by plane table and aerial photographs, section corners being used as control points. Topography was not mapped.

Previous geologic investigations of the Phosphoria formation of this area were undertaken by C. F. Bowen, 1/; D. D. Condit, 2/; and A. P. Butler, Jr.,

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1/ Bowen, C. F., Phosphatic oil shales near Dell and Dillon, Beaverhead County, Montana: U. S. Geol. Survey Bull. 661-I, pp. 315-328, 1918.

2/ Condit, D. D., Oil shale in western Montana, southeastern Idaho, and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 711-B, pp. 15-40, 1919.

C. W. Chesterman (1944, unpublished).

GEOGRAPHY

Most of the mapped area is in the southern part of the Willis quadrangle and includes T. 9 S., Rs. 9-11 W.; secs. 19-23, 26-36, T. 8 S., R. 9 W.; secs. 23-26, 34-36, T. 8 S., R. 10 W.; secs. 5-8, T. 10 S., R. 10 W.; and secs. 1-4, 10-12, T. 10 S., R. 11 W. The Dell area is 20 to 25 miles by highway south of the main area, and outside the limits of the Willis quadrangle.

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U. S. Highway No. 91 and the Oregon Short Line branch of the Union Pacific Railway cross the main area along the Beaverhead Valley from Barretts to Armstead and pass a few miles east of the Dell area. Stock-camp supply roads and trails are passable but slow routes to nearly all parts of the country adjacent to main roads.

The drainage is well developed, but only a few streams are perennial. Beaverhead River and Horse Prairie Creek generally flow through wide, flat valleys, but the valleys are mostly narrow in the area under immediate consideration. Tributary streams, mostly intermittent, have eroded deep V-shaped valleys and canyons, resulting in rough, mountainous topography. The relief seldom exceeds 1,000 feet in most of the area, but is 2,000 feet or more in the vicinity of Dixon Mountain and Timber Butte in the Dell area.

Grasses and sage brush commonly grow where soil mantle has accumulated. Slopes underlain by Quadrant quartzite or covered by talus derived from the Quadrant usually support a growth of evergreens. Elsewhere trees are present only in small patches on north slopes of hilly areas.

STRATIGRAPHY

The rocks in the area are marine and continental sedimentary formations, volcanics, and an intrusive-metamorphic complex. The sedimentary formations, representing all of the geologic periods from the Carboniferous to Tertiary, are briefly described below.

Sedimentary rocks

Lodgepole and Mission Canyon limestones.—The Lodgepole and Mission Canyon limestones of Mississippian age are the oldest Paleozoic rocks exposed in the mapped area. These formations crop out in two north-south strips, one between Small Horn Canyon and Daly's Spur and another between Daly's Spur and Cedar Creek where they underlie most of the high country immediately west of U. S. Highway No. 91 from Pipe Organ Lodge to Armstead.

These Mississippian limestones are gray on fresh surface, light gray on weathered surface, fine-grained, fossiliferous, and resistant to erosion. Three mappable units are recognized: the lowermost, mapped as the Lodgepole limestone, consists of fossiliferous limestone beds 1/4 foot to 2 feet thick which are characteristically contorted into minor complex folds; the middle unit consists of massive beds and rarely shows structure; the uppermost unit consists of beds 1 to 4 feet thick. The two upper units were mapped as the Mission Canyon limestone. None of the units has been measured.

Amsden formation.—The Amsden formation (Mississippian and Pennsylvanian) consists of carbonate rocks, cherts, sandstones, and shales. The beds are gray, light brown, and dusky red, and contrast with the underlying gray Mississippian limestone and the overlying light-gray Quadrant quartzite. Fossils are abundant in some exposures. The Amsden formation is approximately 700 feet thick in the Dell area and about 150 feet thick in the Cedar Creek area.

Quadrant quartzite.--The Quadrant quartzite (Pennsylvanian) consists of massive beds of light-gray, fine- and medium-grained siliceous sandstones and quartzites. Locally, crossbedding is conspicuous, and a few talus blocks contain ripple marks. Approximately 400 feet of the upper part of the Quadrant quartzite is exposed in the cliff at Daly's Spur, and a complete section of approximately 2,000 feet is exposed in Big Sheep Canyon in the Dell area. The Quadrant has been eroded into prominent ridges that may serve to locate the position of the phosphatic shale member of the Phosphoria formation. Commonly quartzite talus slopes cover much or all of the formations that crop out at lower elevations.

Phosphoria formation.--The stratigraphy and lithology of the Phosphoria formation (Permian) vary considerably within the mapped area. In the Dell area the Phosphoria formation has been divided into five mappable units including two phosphatic zones. These five members are shown on the geologic map (pl. 2) as Ppa, -b, -c, -d, -e, (base to top) where mapped as individual units.

The lower siliceous and carbonate member (Ppa) consists of massive beds of carbonate rock, sandstone, siltstone, and chert. Most of the beds are light gray. The beds are 1 to 16 feet thick and are less resistant to erosion than the underlying Quadrant quartzite. The basal bed is carbonate rock. The upper 111 feet consist of pale reddish-brown and dusky-yellow siltstone and gray limestone. The member is 347 feet thick.

The lower phosphatic shale member (Ppb) consists of 54 feet of phosphate rock, mudstone, and chert. The basal 9 feet contain 6.3 feet of phosphate rock.

The upper siliceous and carbonate member (Ppc) consists of 200 feet of chert, sandstone, and carbonate rock in massive beds 2 to 4 feet thick.

The upper phosphatic shale member (Ppd) is conspicuous throughout the mapped area except in sec. 3, T. 10 S., R. 11 W., where it was not recognized with certainty. The member consists of mudstone, phosphate rock, and thin beds of limestone. Light gray, medium gray, and grayish black are the dominant colors. Some of the grayish-black mudstones are petroliferous. In the Dell area the member is 83 feet thick and contains a phosphate zone from 5 feet to 11.3 feet above the base.

The top member (Ppe) consists of 148 feet of cherty and non-cherty mudstones and siltstones in the Dell area.

In the Daly's Spur area (pl. 1) the lower siliceous and carbonate member (Ppa) is 30 feet thick and the lower phosphatic shale member (Ppb) is 5 feet thick. Members Ppa and -b are too thin to be mapped separately and, therefore, are included in member Ppc. Member Ppc consists of chert and sandstone and is 90 feet thick. Member Ppd is 54.5 feet thick and similar to member Ppd of the Dell area. A phosphate zone occurs from 3.8 feet to 12.8 feet above the base of the member. The chert and quartzite member (Ppe) consists of alternating massive beds of nodular chert and quartzites. The dominant color of unweathered rock is gray, and of weathered rock yellowish brown. This member is 136 feet thick at Daly's Spur.

In the Cedar Creek area members Ppa, -c, -d, and -e are similar in lithology to their equivalents in the Daly's Spur section. The lower phosphatic shale member (Ppb) has not been recognized within the area, and the upper shale member (Ppd) appears to be absent in sec. 3, T. 10 S., R. 11 W.

Dinwoody formation.—The Dinwoody formation (Lower Triassic) includes shales, sandstones, and limestones. Light yellow and brown are the dominant colors in fresh exposures. A chocolate-brown color characterizes weathered rock. Four mappable units are recognized. The basal member (TRda) consists of shales with a few thin-bedded sandstones and limestones. This member grades upward into thin-bedded limestone (TRdb). The overlying member (TRdc) consists of reddish shales. The top member (TRdd) consists of thin-bedded limestone similar to TRdb and grades upward into olive-brown shales. The Dinwoody formation is 700 to 800 feet thick in the mapped area and is apparently conformable on the underlying Phosphoria formation.

Fossils are abundant in the limestone beds. Disc-shaped crinoid columnals and small black Terebratula shells are fairly abundant in the basal beds. A few ammonites have been found in the lower sandstone beds; star-shaped crinoid columnals occur in the upper beds.

Thaynes limestone.—The Thaynes limestone (Lower Triassic) consists of two mappable units, each about 80 feet thick. The lower unit (TRta) consists of light-gray sandstone, and the upper (TRtb) consists of pinkish-gray limestone. Star-shaped crinoid columnals are common, and small ammonites are locally abundant in the upper unit. In the Dell area the topmost beds consist of nodular chert.

Ellis formation.--The Ellis formation (Jurassic) has been identified only in the Dell area where it is 360 feet thick and consists of sandstones, limestones, mudstones, and shales. The basal bed is a sandstone, which locally contains a chert breccia derived from the underlying chert nodules of the uppermost Thaynes. The formation is dominantly gray and weathers yellowish gray and yellowish brown. Fossils are abundant and include crinoid columnals (Pentacrinus), pelecypods, and gastropods. The Ellis formation is apparently conformable on the Thaynes limestone.

Kootenai formation.--The Kootenai formation (Lower Cretaceous) consists of a basal conglomerate or conglomeratic sandstone overlain by sandstones, shales, and limestones. The basal conglomerate and sandstone contain abundant black chert pebbles and grains, respectively. The conglomerate grades laterally and vertically into conglomeratic sandstone. The sandstones are light gray and dark greenish gray (pale reddish brown when weathered). Overlying the sandstone are shales that weather to a pale, reddish-brown mantle. Near the top of the formation two massive, gray, gastropod-bearing limestone beds are present; gastropods are particularly abundant in the upper bed.

Early Tertiary conglomerate.—A boulder, cobble, and pebble conglomerate is exposed in many square miles of the mapped area. It is approximately 1,000 feet thick in Clark Canyon (sec. 35, T. 9 S., R. 10 W.) and at least 5,000 feet thick at McKnight Canyon in the Dell area. The age of the conglomerate is tentatively considered to be early Tertiary.

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In the Dell area the conglomerate formation can be divided into three mappable units (pl. 2): a lower conglomerate unit (Tca) at least 2,000 feet thick, a middle unit (Tcb) of limestone, sandstone, tuffaceous shale, and some 1- to 4-foot beds of conglomerate, and an upper unit of conglomerate (Tcc).

The two conglomerate units consist mostly of rounded and subrounded limestone pebbles, cobbles, and boulders. Rounded and subrounded quartzite fragments are present almost without exception and locally make up as much as 95 percent of the conglomerate. Quartzite fragments are white, gray, pink, and red. Some boulders have been derived from a pre-existing conglomerate, and probably most of the quartzite fragments were derived from pre-Cambrian rocks not now exposed in the area. Limestone fragments were derived mainly from the gray Madison limestone. Mantle developed upon the conglomerate in light red, gray, and pale yellowish orange. The light-red color is characteristic of the conglomerate consisting mostly of quartzite fragments. The gray and yellow colors develop upon weathered conglomerate consisting mostly of limestone fragments.

The limestone is massive, light gray and light brownish gray, fine-grained and locally concretionary and sandy. The concretions are as much as 2 inches in diameter, and on weathered surfaces exhibit a striking concentric banding. A few poorly preserved gastropods have been found in the limestone.

In the Willis quadrangle, the early Tertiary (?) conglomerate unconformably overlies all the formations from the Lodgepole to the Kootenai. An angular unconformity between the conglomerate and the Kootenai formation is exposed near the mouth of Grasshopper Creek (SE 1/4 sec. 26, T. 8 S., R. 10 W.), and one between the conglomerate and Mississippian limestone is exposed on the west side of U. S. Highway No. 91 near the south line of sec. 32, T. 9 S., R. 10 W. Tertiary lavas overlie the conglomerate from Grasshopper Creek to Pipe Organ Lodge.

The conglomerate has been folded and is overthrust by the Madison limestone. One overthrust parallels U. S. Highway No. 91 on the west side and extends from sec. 9 to sec. 32, T. 9 S., R. 10 W. Another overthrust can be followed for more than 2 miles at the head of McKnight Canyon in the Dell area.

Tertiary igneous rocks

Extrusive rocks.--Rhyolite, andesite, basalt, and tuff comprise Tertiary extrusive rocks in the mapped area. All are included under a single symbol on the accompanying map.

Intrusive rocks.--A metamorphic complex that includes well-stratified beds of marble, quartzite, and schist extends northward across T. 9 S., R. 11 W. These metamorphic rocks are intruded by a coarse-textured granitic rock consisting of quartz, feldspar, and muscovite. A hornblende gneiss surrounds the granite and apparently is in contact with Mississippian limestone which is slightly altered and contains small aggregates of mineralized rock near the contact. The granite and hornblende gneiss are tentatively considered to be early Tertiary.

STRUCTURE

The sedimentary rocks of the area have been deformed into open and closed folds, and have been faulted. The folding and faulting become more complex to the west. Most folds trend north and many have been overturned to the east. Complex high-angle faulting and overthrusting have occurred in various parts of the mapped area.

Small Horn Canyon area.--The Small Horn Canyon area, along the east side of T. 9 S., R. 9 W., is accessible by road from Dillon or Barretts. The Mesozoic and Paleozoic rocks of this area have been folded into the north-trending anticline at Small Horn Canyon and the syncline at Sheep Creek, both of which plunge northward. The west limb of the anticline and the east limb of the syncline have been deeply dissected by Small Horn Creek and Sheep Creek, respectively. The east limb of the anticline (line between secs. 11-12, 13-14) has been overturned and possibly faulted. Small Horn Canyon may parallel a fault, as the creek has cut into the structure in an unusual manner and the Quadrant quartzite at the mouth of the canyon is offset parallel to the canyon.

The north-facing slope from Sheep Creek to the warm spring in sec. 28, T. 8 S., R. 9 W., is apparently the continuation of the east limb of the Sheep Creek syncline which has been bent to the northwest. On this structure, strike faults have cut out some beds and possibly one or more formations. Dip faults and oblique faults have offset formations a few to many tens of feet. In places the sandstone and quartzite beds of the lower Phosphoria and Quadrant formations have been silicified and sparsely impregnated with pyrite.

The upper phosphatic shale member of the Phosphoria formation can be followed by outcrop, float, and topography for at least 5 miles on the flanks of the Small Horn Canyon anticline and Sheep Creek syncline.

Daly's Spur area.--The Daly's Spur area is mostly within sec. 36, T. 8 S., R. 10 W., on the west side of U. S. Highway No. 91. The west-dipping Mesozoic and Paleozoic rocks of this area crop out on a north-trending homocline which has been deeply eroded and partly buried by early Tertiary (?) conglomerate and Tertiary lavas. They are exposed for about 1 mile along U. S. Highway No. 91 between Grasshopper Creek and Daly's Spur, and are overlain by Tertiary lavas north of Grasshopper Creek and by conglomerate and lavas west and south of Daly's Spur. The beds strike N. 6°-12° E. and dip 35°-65° W. The upper phosphatic shale member of the Phosphoria formation can be traced for half a mile north of Daly's Spur and reaches an altitude of 200 feet above the valley floor. Just east of Daly's Spur station the Dinwoody formation is faulted down against the Quadrant quartzite.

Doll area.--The Doll area in the Tendoy Mountain range south of the Willis quadrangle includes secs. 14-15, 21-23, 26-28, 33-36, T. 12 S., R. 10 W.; the eastern two-thirds of T. 13 S., R. 10 W.; secs. 19-20, 29-31, T. 13 S., R. 9 W.; and secs. 2-3, 10-11, T. 14 S., R. 10 W. It may be reached by road from Kidd or Doll.

Mesozoic and Paleozoic rocks are exposed in a north-trending syncline which which is deeply eroded on the west and covered by the early Tertiary (?) conglomerate and later Tertiary sediments and lavas.

Both limbs of the syncline are characterized by complex faults. A high-angle normal fault parallels the Tendoy Mountain front on the east. Along this fault the Thaynes limestone has been displaced downward against the Phosphoria formation between Little Water Canyon and Dry Canyon and against the Quadrant quartzite south of Dry Canyon. The west limb of the syncline is complexly faulted into small blocks, and many beds and some entire units of the various formations have been eliminated. Thrust faulting is closely associated with the high-angle fault zone of the west limb, which may be the root zone of the thrust faulting as both fault types are closely associated with the overturned west limb. The Mississippian limestones form the topmost plate in the overthrust segment. This plate rests on the Quadrant, Phosphoria, Dinwoody, and Thaynes formations, and early Tertiary (?) conglomerate. These formations pass under the Mississippian limestones north of Little Water and McKnight Canyons and reappear in the area just south of Horse Prairie Valley.

The two phosphatic shale zones can be traced by outcrop, float, and topography for more than 5 miles in the Dell area.

Cedar Creek area.--The Cedar Creek area includes secs. 13-36, T. 9 S., R. 11 W., and secs. 1-4 and 10-12, T. 10 S., R. 11 W., and can be reached by stock-camp supply roads that branch from a county highway west of the mapped area.

Paleozoic and Mesozoic rocks crop out on the limbs of several north-trending asymmetrical anticlines and synclines. The beds on the east limbs of the anticlines are almost vertical or slightly overturned to the east; those on the west limbs range in dip from 20° to 90° W. Locally the structures are doubly plunging. The folds are tightly compressed and faulted in secs. 16-17 and 28-29, T. 9 S., R. 11 W., and are almost recumbent in sec. 20.

The beds are displaced by several high-angle normal faults and by two low-angle thrust faults. The high-angle normal faults include both strike and transverse types. On the strike faults the displacement is not large, but on the transverse fault in secs. 2-3 and 11, T. 10 S., R. 11 W., a displacement of approximately 2,000 feet is indicated. A thrust fault of large displacement occurs northeast of the Cedar Creek area. Along this thrust Mississippian limestone has overridden early Tertiary (?) conglomerate.

Only one thin phosphatic shale zone was recognized in this area and in most places it was too thin to be mapped as a separate unit. It is immediately beneath the upper siliceous member of the Phosphoria formation.

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