GEOLOGIC MAP OF THE PHOSPHATE RESERVE IN THE LANDER AREA, FREMONT COUNTY, WYOMING

By Willis L. Rohrer

GEOLOGY

The area was mapped as part of the U.S. Geological Survey program of classifying and evaluating lands in the public domain. Resources of economic interest in the map area include oil, gas, water, phosphate rock, gypsum, and analcime. The area mapped includes the rocks between the Tensleep Sandstone and the Morrison Formation and Tertiary and Quaternary deposits.

OIL, GAS, AND WATER

All oil and gas exploration in the area has been unsuccessful, although a well in sec. 14, T. 31 N., R. 99 W. (table 1), had an oil show in the Phosphoria Formation. The Phosphoria and Park City Formations and the Tensleep Sandstone produce oil and gas in adjacent areas. Table 1 lists most of the wells drilled in the area, many of which were originally drilled for oil and gas. Whitcomb and Lowry (1968) showed many of the water wells in the Wind River basin and listed flow data.

Although several streams cross the map area, subsurface water is sought by ranchers. The Phosphoria and Park City Formations may yield water in a well in sec. 28, T. 33 N., R. 100 W., but the identification of the aquifer is uncertain. In a plugged well in sec. 29, T. 33 N., R. 100 W., water was found in the Amsden Formation. This is the only reported occurrence of water in the Amsden in the map area. No water was reported in the Tensleep in this well. About half a mile north of this well, a spring along Squaw Creek yields sulfurous water. The water may come from fractures in the Amsden or the Tensleep.

TABLE 1. – *Wells drilled in map area*

Location	Surface formation	Total depth (ft)	Remarks
		T. 31 N., R. 99 W.	
NE¼NE¼ sec. 5	Red Peak	980	Bottom: Phosphoria and Park City.
SE¼NE¼ sec. 9	do.	1,200	Tensleep water well.
SW¼SW¼NE¼ sec. 9	do.	221	Bottom: Red Peak.
SW¼SW¼NW¼ sec. 10	do.	1,507	Probable Tensleep water well.
SE¼SE¼NW¼ sec. 13	Mowry(?)	3,340	Bottom: Tensleep.
NE¼SE¼NW¼ sec. 14	Sundance	2,585	Oil show: middle of Phosphoria and Park City; water: top of Tensleep.
SE¼SE¼NW¼ sec. 26	Red Peak	No records.	Flowing water.
SE¼SE¼NW¼ sec. 27	Park City	1,150	Bottom: Madison Limestone.
		T. 33 N., R. 100 W.	
SE¼NW¼ sec. 18	Red Peak	900	Probable Tensleep water well.
NE¼SW¼ sec. 18	do.	No records	Shut-in water well; strong sulfur odor.
SE¼NW¼SW¼ sec. 28	do.	470	Phosphoria and Park City water well; data questionable.
E½SW¼SE¼ sec. 29	Park City	1,429	Water in Amsden.
NE¼NW¼NW¼ sec. 33	Red Peak	1,021	Tensleep water well (Whitcomb and Lowry, 1968).
		T. 33 N., R. 101 W.	
NW¼NE¼ sec. 13	Red Peak	700	Tensleep water well.
		T. 34 N., R. 101 W.	
NE¼SE¼ sec. 36	Popo Agie and Crow Mountain	2,600(?)	No records, no water.

The best potential for subsurface water is from the Tensleep Sandstone. The water from the Tensleep has a sulfurous odor, but the presence of sulfur is a benefit in irrigation of alkaline soils. The Tensleep locally does not yield water. The absence of water in the well in sec. 36, T. 34 N., R. 101 W., may be because a nearby fault acts as a permeability barrier within the Tensleep or because the throw of the fault has caused the water to be diverted eastward. Of the two wells in sec. 18, T. 33 N., R. 100 W., the northernmost well is most probably flowing water from the Tensleep, but the water of the shut-in well is much more sulfurous than that in other wells in the Tensleep and its origin is unknown. The more promising sites for drilling for water in the Tensleep are those areas adjacent to perennial streams and within half a mile downdip of the recharge areas.

PHOSPHATE

Several investigations of the phosphate deposits in the Lander, Wyo., area have been made. Condit (1924) identified two phosphate-bearing units of the Phosphoria Formation and determined the thickness and quality of the phosphatic beds. King (1947) mapped the Phosphoria and Park City Formations and calculated phosphate resources from Baldwin Creek southeast to Cherry Creek. At Little Popo Agie River and at Baldwin Creek, King measured outcrops and trenched sections of the Phosphoria and Park City. Measured sections and descriptions of equivalent strata (Sheldon and others, 1953; McKelvey and others, 1959; Sheldon, 1963) have been used as a basis of correlation for the various members of the Phosphoria and Park City. These sections are used herein for basic stratigraphic control. King and Schumacher (1949) described the results of a drilling program by the U.S. Bureau of Mines of the phosphate deposits in the Little Popo Agie River and Twin Creek areas. Duncan and Fisk (1957) discussed the phosphate rock of central Wyoming. Coffman and Service (1967, p. 76-89) summarized the occurrence of phosphate deposits in the map area. Reports that pertain chiefly to stratigraphic and structural relations of the formations are listed in "Selected reference."

The Phosphoria and Park City Formations are divisible into six members in the Lander area (McKelvey and others, 1959, p. 16; Sheldon, 1963). These are, from oldest to youngest, the Grandeur, Meade Peak Phosphatic Shale, Franson,[1] Retort Phosphatic Shale, Tosi Chert, and Ervay Members. The Tosi, Retort, and Meade Peak are members of the Phosphoria Formation, and the Ervay, Franson, and Grandeur are members of the Park City Formation. Because the members are generally too poorly exposed for easy distinction, the formations were divided into three units for mapping purposes: the Grandeur; the Meade Peak and Franson; and the Retort, Tosi, and Ervay. These map units facilitate recognition of the stratigraphic positions of the phosphatic beds because the lower and upper phosphate beds are at the bases of the Meade Peak and Retort Phosphatic Shale Members, respectively.

Table 2 shows the estimated phosphate resources in the map area based on the lowest entry levels and with minimum cutoff at 3 feet of 18 percent P_2O_5. Areas that may be exploitable by strip mining are listed separately from the other areas. Strippable, as used in table 2, specifically refers to an isolated or nearly isolated phosphate deposit that has less than 30 feet of cover.

[1] In the Lander area the Franson Member includes beds not directly assignable to that member.

GYPSUM

The Gypsum Spring Formation contains several thin gypsum beds in the upper part and thick massive gypsum beds in the lower part. Where the massive gypsum, locally as much as 40 feet thick, does not outcrop, it may be covered by colluvium resulting from solution of the gypsum and slumping of overlying beds. A prospect for gypsum is near the W ¼ cor. sec. 26, T. 33 N., R. 100 W.

ANALCIME

Analcime, a hydrous sodium aluminum silicate, was first recognized in the Popo Agie Formation by Keller (1952). The lower 12 feet of the Lyons Valley Member contains minor amounts of analcime, and the upper 50 feet has a relatively high analcime content. Preliminary X-ray diffractometer analyses of two samples from the upper part of the Popo Agie indicated:

	Sample 1 (percent)	Sample 2 (percent)
Analcime-----	24	29
Quartz-------	31	39
Calcite-------	44	------
Clay---------	<5	(?)30

The sodium of these samples is less than 4 percent. Large quantities of low-grade analcime-bearing rock are in the Lander area.

STRUCTURAL FEATURES

The map area lies on the northeast flank of the uplifted Wind River Range. All faults and folds are seemingly related to this uplift and are believed to have formed during or shortly after the uplift. The largest faults are reverse faults, and normal faults have small displacements. Some faults, such as the Willow Creek fault, that seem to be normal faults locally show reverse movement. Small bedding-plane faults were seen only outside the map area, but are inferred within the area from relatively minor fold structures.

The most extensive fault is the Bragg Mountain reverse fault that crosses Bragg Mountain near its summit. An estimated 50 feet of vertical displacement and a 52° NE. dip was observed on this fault near the Hart Ranch. The fault extends from at least as far as Charcoal Spring, 1½ miles northwest of the Hart Ranch, southeastward into Baldwin Creek. Near Baldwin Creek the dip of the fault plane may be as low as 35°. Another fault, also at the Hart Ranch, intersects but does not cut the Bragg Mountain fault. This is a low-angle thrust fault that dips southwest at 20° and has a horizontal displacement of about 50 feet. The writer believes this to be a splinter of an unseen bedding-plane fault within Cambrian shales.

A small asymmetric anticline in the NW¼ sec. 19, T. 32 N., R. 99 W., is apparently within the Gypsum Spring Formation. The dip slope on the formation shows a small local reversal in dip that forms a low anticlinal bulge parallel to

TABLE 2. – *Estimated phosphate reserves*

[Based on lowest entry levels with minimum cutoff at 3 feet of 18 percent P_2O_5. Thicknesses and analyses from Condit (1924) and King (1947). Acreage for tonnage planimetered by R. R. Trengove]

Location	Upper phosphate bed			Lower phosphate bed		
	Millions of short tons	Thickness (ft)	P_2O_5 (percent)	Millions of short tons	Thickness (ft)	P_2O_5 (percent)
North of North Fork Canyon	5.0	4.5	19–20	--------	--------	--------
North Fork Canyon to Mexican Creek	3.5	3.3	18–19	--------	--------	--------
Mexican Creek to Chimney Gulch						
Chimney Gulch to Squaw Creek	8.8	4.0	18–20	--------	--------	--------
Ferguson Gulch to Squaw Creek	--------	--------	--------	1.9	3.3	20–22
Squaw Creek to Quakenstead Gulch	20.5	4.0	19–20	--------	--------	--------
Squaw Creek to Sinks Canyon	--------	--------	--------	30.0	3.4	19–22
Quakenstead Gulch to Sinks Canyon	7.6	4.1	19–20	--------	--------	--------
Sawmill Creek area (strippable)	--------	--------	--------	0.5	3.6	22
Sinks Canyon to center sec. 22, T. 32 N., R. 100 W.	14.8	5.0	19–20	--------	--------	--------
Center sec. 22 to Willow Creek	20.8	6.0	19–20	--------	--------	--------
Sinks Canyon to Willow Creek	--------	--------	--------	37.0	3.6	19–28
Halls Gulch-Browns Canyon area	8.7	6.0	17–20	17.9	3.7	19–20
Halls Gulch-Browns Canyon area (strippable)	--------	--------	--------	1.3	3.7	19–20
Willow Creek to Weed Draw	--------	--------	--------	10.1	3.6	22–24
Weed Draw to Little Popo Agie Canyon	--------	--------	--------	17.3	3.9	22–24
Little Popo Agie Canyon to Cherry Creek	--------	--------	--------	12.7	5.1	19–26
Cherry Creek to Weiser Draw	--------	--------	--------	16.9	5.6	19–21
Weiser Draw to Deep Creek	--------	--------	--------	12.7	4.6	19–21
Weiser Draw-Deep Creek area (strippable)	--------	--------	--------	3.0	4.6	19–21
Derby Springs Draw	--------	--------	--------	1.7	5.3	19–20
Deep Creek to State Hwy. 28	--------	--------	--------	14.2	6.0	19–24

the strike of the formation. If this fold is within the formation, it is inferred to result from gravity sliding along bedding.

An asymmetric anticline, named the Hidden anticline (McKay, 1948), is present between Red Canyon and Barrett Creeks. The regional dip near Hidden anticline is 10°–12° NE. The dip on the east limb of the anticline ranges from 9° at the north end to 17° at the south end. The steep west flank of the anticline dips 45°–52° W. Structural closure on the Phosphoria and Park City Formations at the crest of the anticline is about 560 feet. A low-angle reverse fault, dipping 26° NE., can be traced about 0.5 mile at the steeply plunging south end of the anticline, but the fault does not offset the surface strata on the steep west flank. Offsetting of strata along this fault seems to diminish upward.

A fault, apparently normal, with vertical dip and 20 feet of displacement, is present near the Cady Ranch in the W½ sec. 10, T. 31 N., R. 99 W. As partly shown by the structure contours, this fault is presumed to connect with the subsurface trace of the Hidden anticline reverse fault. The anticline, the adjacent syncline, and the fault system are compatible with incipient overthrusting by the anticlinal block or with bedding-plane faulting and underthrusting by the synclinal block.

Another faulted asymmetric anticline very similar to the Hidden anticline, here called the Wolf Point anticline, is between Little Popo Agie Canyon and Willow Creek. McKay (1948, p. 43, 44) described the Wolf Point reverse fault as having about 6,000 feet of surface trace and a maximum displacement of about 800 feet. The displacement and the structural relief of the Wolf Point anticline and the adjacent syncline diminish northward. The fault trace is nearly coincident with the fold axes. The Wolf Point anticline is bounded on the west by steeply dipping strata that are broken in the subsurface by the Wolf Point fault and on the north by the Willow Creek reverse fault. The southward dip of the Willow Creek fault varies from near vertical to 45° or less. The vertical displacement of this fault is about 30 feet at the Sundance-Morrison contact, 60 feet at the Nugget-Gypsum Spring contact, 11 feet with 42 feet horizontal displacement at the Alcova Limestone, and about 80 feet at the mouth of Willow Creek canyon. The southward migration with depth of the Willow

Creek fault, as shown by the structure contours, is inferred because no subsurface control is persent.

Another reverse fault, the Halls Gulch fault, begins as a small monoclinal fold west of and near the mouth of Willow Creek canyon. The Halls Gulch fault is alined with the Willow Creek fault, but the north block is uplifted relative to the south block. Westward, the Halls Gulch fault bifurcates and both parts cross the interfluve into Crooked Creek. The Halls Gulch fault and the Wolf Point fault have the same downthrown mountainward block. The other described reverse faults are similar in that the mountainward blocks moved downward relative to the basinward blocks. The Willow Creek fault is an exception, but in the subsurface it is believed to tie into the Wolf Point fault with the same relationship as the faults at Hidden anticline.

Several examples of near-surface gravity sliding are present in the area. Near-surface gravity sliding along bedding planes is chiefly controlled by two fixed factors the angle of dip and the degree of incompetency of the strata – and one variable factor – the amount of water contained within the strata. The dip slopes within the map area are mostly within the margin of stability for the moisture contained within the strata. However, the dip slopes have been on the verge of gravity sliding during earlier periods of the Holocene and Pleistocene. Near-surface gravity sliding in the incipient stage of slope disruption is shown by bowing of the strata as in the E½ sec. 14, T. 33 N., R. 101 W. The surface of the undifferentiated Phosphoria and Park City Formations is shown by the structure contours to be bowed without disruption of the strata. The incipient sliding includes more than 200 acres, and slippage is probably within the Franson Member. A later stage of gravity sliding is shown by the small landslide area within the Sundance Formation in the NE¼ SE¼ sec. 6, T. 33 N., R. 101 W. At this locality the strata are partly disrupted and partly bowed. The lower margin of the slide area is marked by a bulge in which the strata are broken. The small anticlinal fold within the Gypsum Spring Formation, NW¼ sec. 19, T. 32 N., R. 99 W., is probably a slightly different example of such bulging. Complete disruption of overlying strata is typified by the large landslide area in sec. 7, T. 31 N., R. 99 W.

SELECTED REFERENCES

Bayley, R. W., 1965, Geologic map of the Miners Delight quadrangle, Fremont County, Wyoming: U.S. Geol. Survey Geol. Quad. Map GQ–460.

Burk, C. A., 1957, Stratigraphic summary of the nonmarine Upper Jurassic and Lower Cretaceous strata of Wyoming, *in* Wyoming Geol. Assoc. Guidebook 12th Ann. Field Conf., Southwest Wind River Basin, 1957: p. 55–62.

Coffman, J. S., and Service, A. L., 1967, An evaluation of the western phosphate industry and its resources. Pt. 4, Wyoming and Utah: U.S. Bur. Mines Rept. Inv. 6934, 158 p.

Condit, D. D., 1924, Phosphate deposits in the Wind River Mountains, near Lander, Wyoming: U.S. Geol. Survey Bull. 764, 39 p.

Duncan, W. E., and Fisk, H. G., 1957, Central Wyoming phosphate rock – character, processing and economics: Wyoming Univ. Nat. Res. Research Inst. Bull. 6, 60 p.

Keefer, W. R., 1970, Structural geology of the Wind River Basin, Wyoming: U.S. Geol. Survey Prof. Paper 495-D, p. D1-D35.

Keller, W. D., 1952, Analcime in the Popo Agie member of the Chugwater formation [Wyo.]: Science, v. 115, no. 2983, p. 241–242.

King, R. H., 1947, Phosphate deposits near Lander, Wyoming: Wyoming Geol. Survey Bull. 39, 84 p.

King, W. H., and Schumacher, J. L., 1949, Investigation of the Lander phosphate rock deposits, Fremont County, Wyoming: U.S. Bur. Mines Rept. Inv. 4437, 12 p.

Love, J. D., Johnson, C. O., Nace, H. L., Sharkey, H. H. R., Thompson, R. M., Tourtelot, H. A., and Zapp, A. D., 1945, Stratigraphic sections and thickness maps of Triassic rocks in central Wyoming: U.S. Geol. Survey Oil and Gas Invs. Prelim. Chart 17.

Love, J. D., Tourtelot, H. A., Johnson, C. O., Sharkey, H. H. R., Thompson, R. M., and Zapp, A. D., assisted by H. L. Nace, 1945, Stratigraphic sections and thickness maps of Jurassic rocks in central Wyoming: U.S. Geol. Survey Oil and Gas Invs. Prelim. Chart 14.

McKay, E. J., 1948, Geology of Red Canyon Creek area, Fremont County, Wyoming: Wyoming Univ. master's thesis, 68 p.

McKelvey, V. E., and others, 1959, The Phosphoria, Park City, and Shedhorn Formations in the western phosphate field: U.S. Geol. Survey Prof. Paper 313-A, 47 p.

Murphy, J. F., and Richmond, G. M., 1965, Geologic map of the Bull Lake West quadrangle, Fremont County, Wyoming: U.S. Geol. Survey Geol. Quad. Map GQ-423.

Peterson, J. A., 1957, Gypsum Spring and Sundance formations, central Wyoming, *in* Wyoming Geol. Assoc. Guidebook 12th Ann. Field Conf., Southwest Wind River Basin, 1957: p. 47–54.

Pipiringos, G. N., 1968, Correlation and nomenclature of some Triassic and Jurassic rocks in south-central Wyoming: U.S. Geol. Survey Prof. Paper 594-D, p. D1-D26.

Richmond, G. M., and Murphy, J. F., 1965, Geologic map of the Bull Lake East quadrangle, Fremont County, Wyoming: U.S. Geol. Survey Geol. Quad. Map GQ-431.

Sheldon, R. P., 1963, Physical stratigraphy and mineral resources of Permian rocks in western Wyoming: U.S. Geol. Survey Prof. Paper 313-B, p. 49–273.

Sheldon, R. P., Waring, R. G., Warner, M. A., and Smart, R. A., 1953, Stratigraphic sections of the Phosphoria formation in Wyoming, 1949–50: U.S. Geol. Survey Circ. 307, 45 p.

Thompson, R. M., Troyer, M. L., White, V. L., and Pipiringos, G. N., 1950, Geology of the Lander area, central Wyoming: U.S. Geol. Survey Oil and Gas Inv. Map OM-112.

Whitcomb, H. A., and Lowry, M. E., 1968, Ground-water resources and geology of the Wind River Basin area, central Wyoming: U.S. Geol. Survey Hydrol. Inv. Atlas HA-270.