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A SUMMARY OF THE GEOLOGY OF CROOKS GAP, FREMONT COUNTY, WYOMING, AS RELATED TO URANIUM RESOURCES

By
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Introduction

Crooks Gap is the third-most-important uranium district in Wyoming, from the standpoint of both developed ore reserves and past production, ranking behind the Gas Hills and Shirley Basin districts. Crooks Gap is located in Central Wyoming about 30 miles south of the Gas Hills district and some 85 miles west of Shirley Basin. The nearest town is Jeffrey City, seven miles north of Crooks Gap.

Uranium was discovered in Crooks Gap late in 1953 by a jade prospector. Other uranium discoveries soon followed and a number of sizeable ore deposits were blocked out by surface drilling in subsequent years.

Mining of small shallow oxidized ore bodies was begun in 1954, and has continued to the present in a north-south belt of mines in T. 28 N., R. 92 W. Production was comparatively unimportant until late 1957 when Continental Uranium Co. of Wyoming began mining deeper unoxidized ore from the Seismic shaft on the Windy claim group. Continental is still operating the Seismic underground mine, and has a second shaft operation at the nearby Reserve mine on the Golden Goose claim group. A third shaft mine is being developed by Western Nuclear on other claims of the Golden Goose group. Western Nuclear also has an active underground mine from inclined adits on the Snowball group. Green Mountain Uranium Corp. is mining an ore deposit in the NW$\frac{1}{4}$ sec. 16 from a horizontal adit. Some production was obtained from several mines that are now inactive; the more important of these include the

Paydirt and Seismic pits in secs. 20 and 21, and the Sun-Sundog underground mine in sec. 28. Through the end of 1966, Crooks Gap has produced 960,000 tons of ore @ 0.25% U_3O_8. (The locations of the aforementioned mines are shown on the accompanying map.)

Much of the information for this report is based upon the following published reports: "Geology and Uranium Deposits at Crooks Gap, Fremont County, Wyoming", by James G. Stephens, Geol. Survey Bull. 1147-F, 1964; "Preliminary Report on Uranium Deposits in the Crooks Gap Area, Fremont County, Wyoming", by J. F. Whalen and D. Norton, Atomic Energy Commission RME-1082, 1957; "Split Rock Formation (Miocene) and Moonstone Formation (Pliocene) in Central Wyoming", by J. D. Love, Geol. Survey Bull. 1121-I, 1961. In addition, some geological details of the Cooper-Willow Creeks area was acquired from an unpublished map compiled by Harry B. Young while employed by the Atomic Energy Commission. Apology is made for the lack of credits given to other sources of information, but time did not permit searching for all references dredged from memory.

Stratigraphy

Rocks exposed in the Crooks Gap area range in age from Precambrian to Recent. The Precambrian rocks are predominantly coarsely crystalline granite cut locally by basic dikes. The granite crops out at intervals immediately to the north of a fault zone that bounds Green Mountain on the north. The outcrops are probably extensions or outliers of the overthrust Granite Mountains igneous mass.

Paleozoic rocks are largely marine limestone, sandstone, and some shale, and aggregate about 2,000 feet in thickness. The exposed Mesozoic rocks consist of about 9,000 feet of marine shale and some sandstone. The

Mesa Verde and Lance Formations of Late Cretaceous age, although not identified anywhere at the surface, have been logged at depth in some of the oil wells of the area.

Tertiary sediments predominate at the surface of the Crooks Gap area. The oldest is the Fort Union Formation of Paleocene age. The apparently nonmarine Fort Union consists of interbedded thin units of silty mudstone, carbonaceous shale, impure coal, and sandstone lenses. The Fort Union unconformably overlies older rocks, and in turn unconformably underlies the Battle Spring Formation. As a result, the Fort Union varies considerably in thickness and is locally absent. Stephens recognizes up to 1,000 feet of outcropping Fort Union Formation in the Crooks Gap area.

Stephens correlates the early Eocene sediments of Crooks Gap with the Battle Spring Formation in the Great Divide Basin. These same Crooks Gap sediments have been referred to by other authors (e.g., Whalen and Norton) as the Wasatch Formation. The Battle Spring in Crooks Gap consists predominantly of fluviatile arkosic sediments varying from siltstone to boulder conglomerate. Carbonaceous shale and siltstone beds or lenses are present locally. Stephens describes a coarse arkosic lower member, having some Paleozoic constituents,and hosting the uranium ore, and an even coarser boulder conglomerate upper member having a higher percentage of granite constituents. However, he states that the lithologic distinction between the two members dies out at the south end of Crooks Gap, where the sediments are generally coarse-grained arkosic sandstones.

The source of the sediments in the Battle Spring Formation is generally believed to be from granite and some of the Paleozoic formations thrust southward along the Emigrant Trail thrust fault at the close of the Laramide orogency. Stephens reports that subsurface evidence indicates a paucity of Eocene sediments north of the Kirk fault, and theorizes that the granite in the area, presently buried by Oligocene and Miocene sediments, was a pediment surface during Eocene time. He states that the thickest-known Battle Spring is about 4,700 feet at the south edge of Crooks Gap.

Post-Eocene rocks in the area consist of the White River Formation of Oligocene age and the Split Rock (or Arikaree) Formation of Miocene age. Stephens describes the White River Formation as a clayey tuffaceous siltstone and the Split Rock Formation as a fine- to medium-grained tuffaceous sandstone. The White River is exposed only in a few isolated outcrops along the Kirk fault. (However, it is reported that some of the nearly flat-lying sediments capping both Crooks Mountain and Green Mountain has been found to be of Oligocene age, and therefore probably part of the White River; Stephens included these sediments in the Battle Spring Formation.) The Split Rock Formation is the predominant surface rock to the north of the Kirk normal fault, and Stephens reports that the thickest-known section of the formation, 930 feet, was penetrated in an oil well in sec. 4, T. 28 N., R. 93 W. The White River and Split Rock Formatinns are reported by Love, Stephens, and other authors to contain above-normal quantities of uranium.

Geologic History

The pertinent geologic history of Crooks Gap started with the close of the Laramide revolution in Paleocene and early Eocene times. Stephens believes that the Fort Union Formation was probably deposited largely in the synclines and at otherwise lower elevations. In late Paleocene or early Eocene time, the Granite Mountains and flanking sedimentary rocks were uplifted and thrust-faulted southward along the Emigrant Trail thrust. Erosion of the thrust plate stripped much of the exposed Paleozoic rocks and some of the Precambrian granite, redepositing it farther south as the Battle Spring Formation. Thrusting continued sporadically throughout early Eocene time, and most of the eroded rock in the late stages of thrusting was granite. Relative quiescence apparently existed from middle Eocene through Miocene times, although some minor folding, faulting, and regional uplift took place and the White River and Split Rock Formations were deposited. The last significant crustal disturbance was the relative downfaulting of the Granite Mountains block, with considerable downward displacement on the north side of the Kirk normal fault; Stephens suggest that this took place probably throughout much of Pliocene and Pleistocene time. Considerable erosion of the area followed to the present time with formation of the present Sweetwater River drainage system.

Description of Deposits and Ore Controls

The more important Crooks Gap uranium deposits are those that are deep and unoxidized. These deposits are generally larger and more continuous than are the shallow deposits, and occur both above and below the water table. Uranium minerals are uraninite and coffinite. The more common uranium minerals at shallow depth are uranophane and autunite. The shallow deposits are generally small and discontinuous, apparently as the result of oxidation and redistribution. Western Nuclear found little ore in nearly 100 feet of the upper radioactive zone in the Paydirt pit, but mined more ore than was expected from the deeper unoxidized zone; redistribution of ore is illustrated by this mining venture.

In general, it can be said that the ore in Crooks Gap occupies the more permeable beds of the ore-bearing stratigraphic unit. Localization of the ore apparently has been partly influenced by lithologic changes affecting permeability. A reducing environment has been widely discussed as a prerequisite for uranium precipitation; plant-derived carbon trash has localized some Crooks Gap ore, and the action of anaerobic bacteria or the possible existence of hydrogen sulfide have been postulated as additional agents of deposition.

Origin of the Uranium

Three principal theories have been postulated by various authors for the origin of uranium in Central Wyoming. These are: (1) the leaching of slightly uraniferous tuffaceous rocks of the White River and Arikaree (Split Rock) Formations, and possibly similar Pliocene rocks; (2) derivation of the uranium from the uraniferous granite of the Granite Mountains, and; (3) a deep-seated hydrothermal source, access to which may have been provided by the major normal faults in the area.

The theory of origin calling for leaching of the uraniferous Olgocene-to-Pliocene tuffaceous rocks appears plausible, as it is likely that a substantial quantity of these rocks once covered much of the Central Wyoming area. The uranium in these rocks has been postulated to have originated from the magmatic source of the Yellowstone volcanics and was airborne to sites that enabled accumulation in the tuffaceous formations. Although some of the uranium was probably leached from the in-place tuffaceous rocks, as indicated by Love, it seems likely that much of the uranium would not have been introduced into the ground-water system until the weathering and erosion of the rocks. Stephens indicates that erosion of the tuffaceous sediments was probably minor until after downfaulting of the rocks north of the Kirk normal fault had attained significance late in Pliocene time. Therefore, much of the uranium solution, transport, and deposition would likely have taken place since Pliocene time.

Derivation of the uranium from the granites involves leaching of the granitic debris from the Granite Mountains. The process of leaching and redepositing the uranium could have taken place at about any time after the deposition of the arkose in the Battle Spring Formation. One fact that supports the theory of a granite origin is the overwhelming predominance of Central Wyoming arkoses of early Eocene age as the uranium host rock in the three major uranium districts; the Granite Mountains reportedly were the source of all of these host rocks.

A hydrothermal source for the uranium seems less probable, but cannot be conclusively ruled out. The most likely mechanism would be the introduction of ascending hydrothermal solutions into the ground-water system, and subsequent transport by ground water to the sites of deposition.

Uranium Potential

Inasmuch as nearly all of the known uranium deposits in Central Wyoming occur in arkosic sediments of early Eocene age, the Battle Spring Formation will for the present be regarded as the only potential uranium host rock in the Crooks Gap area. The absence of any known Battle Spring Formation north of the Kirk fault in the vicinity of Crooks Gap would seem to negate the potential of that part of the area.

The area to the south of the present uranium deposits has the most obvious potential. The southeast-trending syncline in which the developed uranium deposits occur apparently has acted as a channelway through which the mineralizing solutions moved. Because of the northward closure of the syncline, it seems likely that the solutions moved from north to south. Uranium occurrences that appear to be related to the trend are all of those on the flanks of and at depth under Sheep Mountain. Uranium has also been penetrated at varying depths farther southeastward on the Bluebell group and on new claims (the Wye group) of Utah Construction & Mining Co. about in sec. 7, T. 27 N., R. 91 W. Farther southeastward, a moderate-sized uranium deposit is blocked out on the Alfred group in sec. 34, T. 27 N., R. 91 W. Thus, the mineralized or potential trend can probably be projected southeastward along the steep flank of Green Mountain at least to northwestern T. 27 N., R. 91 W., and possibly farther southeastward beyond the Alfred group.

The ore-bearing syncline in Crooks Gap may flatten out southward toward the Great Divide Basin, as the orogenic forces were probably strongest in the vicinity of the Emigrant Trail thrust fault. Flattening of the folds to the south would tend to broaden the channelway through which the mineralizing solutions moved. For this reason, the potential belt is broadened southward, as shown on the accompanying map. No attempt is made to project the potential southward any farther, as insufficient knowledge of that area is at hand.

Harry B. Young, while employed by the AEC, mapped a second syncline plunging southwestward in the Cooper-Willow Creeks area about 12 miles east of Crooks Gap. Minor uranium occurrences have been found in the vicinity on the Roberts and Stratton leases and the GR group. No information is available on the thickness of the Battle Spring Formation in this area, but

Western Nuclear is reported to have drilled several holes in excess of 1,000 feet deep last summer; a substantial thickness of Battle Spring is implied by the drilling depths. The Alfred group is located about six miles southwest of the Roberts and Stratton leases, somewhat west of a projection of the syncline, and could just as well be included in a potential belt extending from the northeast as from the northwest. Such a potential belt is sketched on the accompanying map, but the favorability of this area has to be considered low with the limited information on hand.

A factor that may have some bearing on the potential south of the Crooks Gap area, and possibly within the Crooks Gap area, is the interior drainage of the Great Divide Basin. There undoubtedly is a condition of stagnant water in the basin at some elevation or elevations that would probably have an adverse effect on uranium transport and deposition. Freely moving uraniferous ground water would seem to be a firm requirement for the accumulation of major uranium deposits.