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URANIUM IN THE SANOSTEE DISTRICT, SAN JUAN COUNTY, NEW MEXICO

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ABSTRACT—The Sanostee district (also known as the Chuska district) is located within the Navajo Indian Reservation, San Juan Basin, San Juan County, New Mexico. On the Reservation all prospecting, leasing and mining was controlled by the Navajo Tribal Council and the Bureau of Indian Affairs. All prospectors had to have a permit. Uranium ore has been produced from the Salt Wash and Recapture Members of the Jurassic Morrison Formation and a small amount of ore has been mined from the Jurassic Todilto Limestone. Total production from the district amounted to 139,399 short tons of ore grading 0.12% U_3O_8 and 0.14% V_2O_5 and containing 332,721 pounds of U_3O_8. During the period 1952 through 1982, the large underground mine on Enos Johnson's mining permit, west of the village of Sanostee, produced 136,665 short tons of ore that averaged 0.12% U_3O_8 and contained 325,927 pounds of U_3O_8. Ores that were analyzed for vanadium averaged 0.14% V_2O_5. This production makes the Enos Johnson mine the largest uranium mine in New Mexico, outside the Grants uranium district. It is likely that additional small deposits could occur in the Sanostee district. However, the Navajo Indian Reservation now has a moratorium on any uranium exploration and mining within its boundaries. Furthermore, the known deposits in the Sanostee district were relatively small compared to the larger more extensive deposits in the Grants uranium district. It is unlikely that any of the deposits in the Sanostee district will be mined in the foreseeable future.

INTRODUCTION

The purpose of this report is to summarize the data related to the uranium deposits in the Sanostee district (also known as the Chuska district), San Juan County, New Mexico. The district is centered around Enos Johnson's Navajo Tribal Mining Permit (Fig. 1) that was located approximately 11 km west of the village of Sanostee. The area can be accessed via a dirt road from the village. Sanostee is from the Navajo, *tse anáoztíí*, meaning layered rocks (Young and Morgan, 1942). This no doubt refers to the mesas both north and south of the village that are capped by the Upper Cretaceous Gallup Sandstone.

The Sanostee district is located within the Navajo Indian Reservation (Fig. 1). On the Reservation all prospecting, leasing and mining was controlled by the Navajo Tribal Council and the Bureau of Indian Affairs. All prospectors had to have a permit. Mining permits and leases were granted by the Navajo Tribal Council and approved by the Bureau of Indian Affairs (BIA), U.S. Department of Interior. Mining permits could be obtained by individual Navajos only. Permit holders could assign the mining rights to another individual or a company; however, as with the permits, these assignments had to be approved by the Tribal Council and the BIA. Leases were issued directly by the BIA, and approved by the Secretary of the Interior. Permits were issued for a 2-year period and could be renewed for an additional 2 years. Leases were issued for a period of up to 10 years. No more than 960 acres of tribal land could be held by any one company or individual. Both the permittee and the tribe would receive royalties from ore production. In addition to mining permits, the tribe issued drilling and exploration permits. These permits were good for 120 days and were not renewable.

In the district, uranium ore has been produced from the Salt Wash and Recapture Members of the Jurassic Morrison Formation. A small amount of ore has been mined from the Jurassic Todilto Limestone. The district is located on the eastern flank of the Chuska Mountains. Here, the rocks dip steeply to the east along the Defiance monocline. Stratigraphic nomenclature and geologic history are described elsewhere in this guidebook and in cited references.

Information on the uranium deposits and production history was acquired by the senior author when he was employed by the U.S. Atomic Energy Commission (AEC) and succeeding agencies: the U.S. Energy Research and Development Administration and the U.S. Department of Energy (DOE). This information has been summarized by McLemore (1983) and McLemore and Chenoweth (1989).

EXPLORATION AND PRODUCTION HISTORY

Uranium deposits west of Sanostee Day School were brought to the attention of AEC geologists in early 1951, by M.W. Watters of Dolores, Colorado. Ellsworth (1951), of the AEC, performed a preliminary reconnaissance of the area on May 2-3, 1951, and reported three areas of strong mineralization spaced about one and a half km apart in the upper unit of the Recapture Member of the Morrison Formation. A radiometric survey of the area was made by AEC geologists, and in June 1951 approximately 1824 m of outcrop was exposed by AEC bulldozing (Droullard and Jones, 1951). After mapping and sampling the rim-stripped area, Droullard and Jones (1951) estimated that a total of 426 short tons averaging 0.35% U_3O_8 had been exposed in nine separate outcrops. They also recommended drilling behind the outcrops, and to test the underlying Salt Wash Member of the Morrison where uranium mineralization also had been located.

The initial discoveries and subsequent rim stripping, was informally claimed by Enos Johnson and Enos Johnson, Jr. of Sanostee. The area was approximately 11 km west of Sanostee School on the north, south, and west slopes of a mesa known as South Peak. The discoveries on the Enos Johnson property triggered a great deal of prospecting in the Jurassic rocks exposed

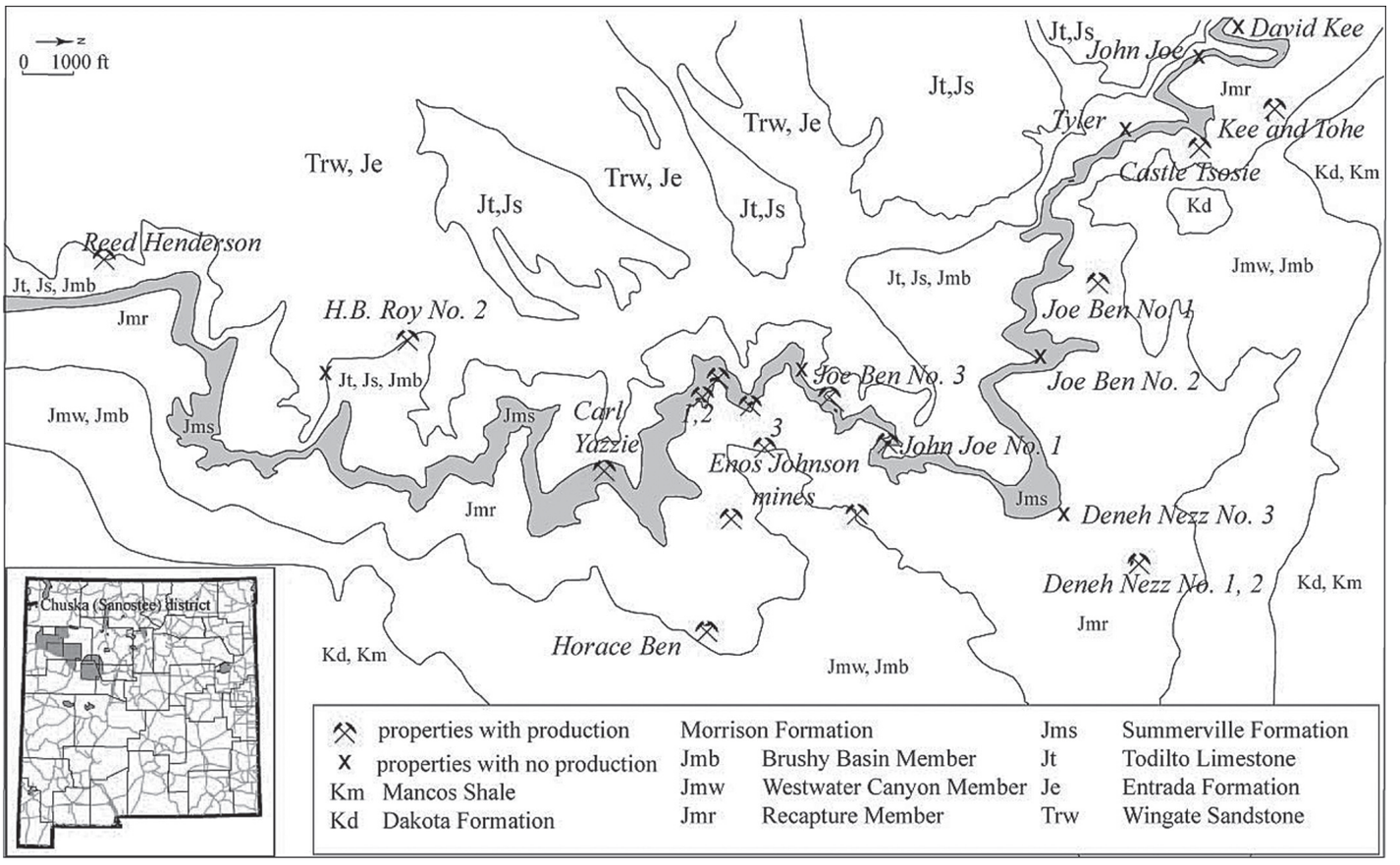

FIGURE 1. Geologic map and location of mines and prospects in the Sanostee district, New Mexico (modified from Blagbrough and others, 1959).

on the east flank of the Chuska Mountains in the Sanostee and adjacent areas.

On January 7, 1952, the AEC opened an ore-buying station at Shiprock, New Mexico. The station, operated by the American Smelting and Refining Company (AS&R), provided a market for ores in northeastern Arizona and northwestern New Mexico, mostly from the Navajo Indian Reservation. The initial shipment of uranium ore from the Sanostee area was received at the Shiprock buying station on June 26, 1952 (AS&R, 1952, written communication). A 6-ton shipment averaging 0.36% U_3O_8 and 0.42% V_2O_5 was received from Joe, Jody B., and Robert G. Rogers, doing business as Rogers and Sons, who had the assignment of Joe Ben's Navajo Tribal Mining Permit (MP) No. 17. This shipment came from a small pod of mineralization in the lower Recapture Member on the north side of Sanostee Wash (Fig. 1).

Navajo Tribal Mining Permit No. 18 was approved to Enos Johnson and Enos Johnson, Jr. on April 26, 1952. The permit covered an area of 819 acres, including the original discoveries and a large area to the east of them. The assignment of the permit to Roland D. Young was approved on August 6, 1952. The initial shipment of ore from the Enos Johnson permit was received at the Shiprock buying station on July 15, 1952 (AS&R, 1952, written communication). It consisted of 18 tons which averaged 0.14% U_3O_8 and 0.23% V_2O_5. Enos Johnson, Sr. was listed as the shipper for the initial 980 tons of ore produced from the property. These shipments averaged 0.10% U_3O_8 and 0.15% V_2O_5, and according to notes in the AEC files, came from the original rim-stripped area in the upper unit of the Recapture.

When Roland D. Young began shipments from the property on September 11, 1952, he continued to designate the rim-stripped areas as the Enos Johnson property. Production from the Salt Wash Member was designated Enos Johnson Nos. 1 and 2, and production from an underground mine in the upper Recapture was initially labeled as the Enos Johnson No. 3. This mine also was known as the South Peak mine (Fig. 1, Table 2). Young did about 762 m of rim stripping in the upper Recapture on the north side of South Peak in 1952. Shipments from this area also would be designated Enos Johnson, without a number.

Other shipments received in 1952 included 4 short tons averaging 0.17% U_3O_8 and 0.24% V_2O_5 from the Horace Ben property (MP-37) in the upper Recapture, operated by J.C. Cox and Glover Rogers southeast of the Enos Johnson mines (Fig. 1), and 115 short tons of "no pay ore" averaging 0.06% U_3O_8 and 0.20% V_2O_5 from the Deneh Nezz permit (MP-42) assigned to Rogers and Sons, covering mineralization in the upper Recapture on the north

side of Sanostee Wash (Fig 1). The spelling of this property has appeared in various forms—Dennet, Denneh, Denet, Nez, etc.; however, the form used in this report is the spelling as it appears on a copy of the Navajo Tribal Mining Permit in the AEC files. Total production in 1952 was 1,742 short tons of ore containing 4,278 pounds U_3O_8, and averaging 0.12% U_3O_8 (Table 1).

In late summer 1953, the AEC carried out a sampling program of the bleached zone in the upper unit of the Recapture on the Enos Johnson permit. This study was to determine if this zone constituted a large, low-grade ore body. The results of the sampling indicated the zone averaged less than 0.05% U_3O_8 (Blagbrough and others, 1959). In September 1953, the AEC had established a reconnaissance camp in the area to study the deposits for possible ore guides and to plan drilling projects. Navajo Indians were employed through the AEC's prime contractor Walker-Lybarger Construction Company to prospect areas considered favorable. Rim stripping was done on several properties, including the Enos Johnson Nos. 1 and 2, the Joe Ben No. 3, and the John Joe properties in the Salt Wash (Fig. 1).

During 1953, production continued to increase on the Enos Johnson permit. Other properties that made shipments during the year included 146 short tons averaging 0.16% U_3O_8 and 0.73% V_2O_5 from the Joe Ben No. 3 mine in the Salt Wash, and 11 short tons averaging 0.11% U_3O_8 and 0.36% V_2O_5 from the Deneh Nezz No. 1 in the upper Recapture (Fig. 1). Both shipments were made by Rogers and Sons.

In 1954, exploration by the various operators included rim stripping, wagon drilling, and aerial radiometric surveys. In addition to production from the Enos Johnson ground, Bee-Sho-Shee Mining Company shipped 23 short tons averaging 0.15% U_3O_8 and 0.76% V_2O_5 from the Carl Yazzie No. 1 property in the Salt Wash, and 47 short tons averaging 0.10% U_3O_8 and 0.28% V_2O_5 from the Kee and Tohe property in the upper Recapture (Fig. 1). Rogers and Sons shipped an additional 17 short tons averaging 0.30% U_3O_8 and 0.76% V_2O_5 from the Deneh Nezz No. 1 prospect.

Two properties in the Todilto Limestone made shipments in 1954. Both are located in the extreme southern part of the area. The Reed Henderson property, operated by Hancock and Hutchison, shipped 24 short tons averaging 0.03% U_3O_8 and 0.11% V_2O_5. Since the grade of the uranium was less than 0.10% U_3O_8, as required by the AEC, no payment was made for the material.

The H. B. Roy No. 2 property (Fig. 1), operated by Bigler and Johnson, made a shipment of 6 short tons averaging 0.10% U_3O_8

TABLE 1. Production from the Sanostee district, San Juan County, New Mexico (from Department of Energy records, National Archives, Record Group 434-00-287, 1980 estimated). No production in 1957, 1960, and 1972-1975.

YEAR	SHORT TONS OF ORE	U_3O_8 (lbs.)	U_3O_8%	V_20_5 (lbs.)	V_20_5%	NO. OF OPERATORS	NO. OF MINES
1952	1,742	4,278	0.12	5,449	0.11	4	7
1953	3,170	11,743	0.19	12,347	0.19	3	5
1954	2,776	8,674	0.16	9,541	0.17	5	8
1955	1,840	7,887	0.21	7,836	0.21	2	4
1956	937	3,564	0.19	3,015	0.16	3	3
1958	1,955	7,006	0.18	5,413	0.14	1	1
1959	444	1,495	0.17	1,277	0.14	1	1
1961	1,565	6,754	0.22	---	---	1	1
1962	4,062	17,421	0.21	6,798	0.12	1	1
1963	4,214	19,550	0.23	10,686	0.13	1	1
1964	3,996	15,942	0.20	7,779	0.10	2	1
1965	2,940	10,086	0.17	6,896	0.12	1	1
1966	3,326	11,252	0.17	11,869	0.18	1	1
1967	1,709	6,264	0.18	6,685	0.20	1	1
1968	1,460	5,486	0.19	4,757	0.16	1	1
1969	242	974	0.20	1,011	0.21	1	1
1970	872	2,856	0.16	---	---	1	1
1971	161	732	0.23	---	---	1	1
1976	12,247	18,899	0.08	---	---	1	1
1977	26,663	40,067	0.08	---	---	1	1
1978	20,753	33,675	0.08	---	---	1	1
1979	14,311	38,479	0.13	---	---	1	1
1980	13,300	28,000	0.11	---	---	1	1
1981	9,397	20,848	0.11	6,947	0.08	1	1
1982	5,156	10,789	0.10	885	0.09	1	1
TOTAL	139,399	332,721	0.12	109,191	0.14	11	16

and 0.28% V_2O_5. Hilpert (1969, p. 51) mistakenly described the H. B. Roy No. 1, as located in the upper Recapture Member in Bear Creek Canyon, as the H. B. Roy No. 2, and credited the production to the sandstone property. Anderson (1981) located a small open pit at the location shown on the map (Fig. 1) by Blagbrough and others (1959, Fig. 5) and confirmed the AEC records that the shipment came from the Todilto.

In July 1954, the AEC began its first drilling project in the Sansotee area. Between July 9, 1954 and January 11, 1955, 33 core holes with a total depth of 5405 m were drilled. Of these holes, 7 penetrated the Todilto Limestone, another 7 were drilled through the Salt Wash, and the remaining 19 were bottomed just below the mineralized zone in the upper unit of the Recapture.

A second project of non-cored holes began on March 29, 1955 and was completed on August 11, 1955. Forty-eight air rotary holes totaling 5715 m were drilled to test the mineralized zone in the upper Recapture. Details of these drilling projects were given by Blagbrough and others (1959) and Collyer (1957). All of the drilling was on the Enos Johnson and Horace Ben properties. Twenty-four of the holes drilled into the upper Recapture Member penetrated uranium grades that exceeded 0.10% U_3O_8. Another 11 holes were mineralized in the range of 0.05% to 0.10% U_3O_8. The uranium located by the AEC drilling would assist in the exploration and development of the Enos Johnson No. 3 mine in the years to come.

Production at the Enos Johnson property continued to decline in 1955. Shipments were made by Rogers and Sons from the Deneh Nezz Nos. 1, 2, and 3 in the upper and lower Recapture, and from the Joe Ben No. 3 and John Joe No. 1 in the Salt Wash (Fig. 1). Early in 1956, Bee-Sho-Shee Mining Company shipped 12 short tons of ore averaging 0.25% U_3O_8 and 0.08% V_2O_5 from the Castle Tsosie property in the upper Recapture, in the northwestern part of the area (Fig. 1). This would be the last ore shipment from the Sanostee area from a property other than Enos Johnson.

Roland D. Young abandoned the Enos Johnson No. 3 mine early in 1956 after shipping 630 short tons of ore averaging 0.18% U_3O_8 and 0.16% V_2O_5. The assignment of the Mining Permit No. 18 was transferred from Roland D. Young to the Shiprock Uranium Corporation on April 19, 1956. Shiprock Uranium produced 295 short tons of ore averaging 0.20% U_3O_8 and 0.16% V_2O_5 before shutting the operation down in the summer of 1956.

Now operated by Shiprock Industries, Inc., the Enos Johnson mine (the designation No. 3 was not used by Shiprock) began producing in the summer of 1958, mining ore that had been discovered by long-hole drilling adjacent to the mine workings. After shipping 1,955 short tons of ore that averaged 0.18% U_3O_8 and 0.14% V_2O_5, Shiprock Industries closed the mine in the spring of 1959. The assignment of their mining permit was cancelled on March 1, 1961.

Mining Permit No. 18 would next be assigned to A and B Mining Company (Ivor Adair and Tom Balsley) on April 20, 1961. Sampling, and prospecting with a jackhammer throughout the mine workings, located additional ore that had been bypassed by previous operators, especially beneath the floor of the mine. A and B began shipments to the Texas-Zinc Minerals mill at Mexican Hat, Utah early in 1961. The Kerr-McGee mill at Shiprock would not accept the Enos Johnson ore because of to its low vanadium content.

On November 15, 1962, the original Mining Permit No. 18 was converted to Mining Permit No. 584, which would include only 69.5 acres. In late 1962, A and B would begin shipping to the Union Carbide Corporation mill at Rifle, Colorado, where the low vanadium ore from Enos Johnson was blended with high vanadium ores from the northern Colorado Plateau area. A and B Mining Co. would continue production until spring 1964 using the previous AEC drilling to guide their exploration. Production under the AEC program reached an all-time high level in 1963, when the Enos Johnson mine produced 4,214 short tons of ore averaging 0.23% U_3O_8 and 0.13% V_2O_5 and containing 19,550 pounds of U_3O_8 (Table 2).

Ray L. Williams acquired the assignment of Mining Permit No. 584 in early 1964 and continued to ship ore to the Rifle mill and to the Uravan, Colorado mill, also operated by Union Carbide Corporation. Williams continued to ship to Colorado until 1970 when he switched to the Atlas Minerals mill at Moab, Utah.

The AEC procurement program terminated at midnight December 31, 1970. By that time the underground mine on the Enos Johnson permit had produced 34,678 short tons of ore averaging 0.19% U_3O_8 and 0.14% V_2O_5. The Enos Johnson mine continued to make shipments to Atlas Minerals at Moab, Utah until the summer of 1971, when the mine closed because of low uranium prices in the private market.

With uranium prices beginning to increase in the mid 1970's, Ray L. Williams reopened the Enos Johnson mine in 1976. Large quantities of low-grade material which had been stockpiled or bypassed during earlier mining were shipped to Moab. From 1976 through 1978, Williams shipped 59,663 short tons of ore averaging 0.08% U_3O_8 (Table 1). On the mill receipts to the DOE, these tons were noted as "dump ore". In 1979 as the prices declined, so did the production at the mine, but the grade increased to over 0.10% U_3O_8. Energy Fuels Nuclear, Inc. began operating their White Mesa mill near Blanding, Utah in 1980 and some Enos Johnson ore was shipped there. Declining market prices forced the Enos Johnson mine to finally close in late 1982. The nearest market, Energy Fuels, near Blanding closed their White Mesa mill in February 1983.

GEOLOGY AND URANIUM DEPOSITS

Todilto Limestone

The Todilto Limestone is an impure, dense gray, very fine-grained, thin-bedded limestone about 3 m thick. It is transitional downward into the Entrada Sandstone and upward into the Summerville Formation. The lower part of the Todilto is formed by flat-lying slabby beds less than 0.3 m thick, and the upper part by beds 0.3 - 0.6 m thick. The upper part of the Todilto contains numerous small folds with some coarsely re-crystallized calcite. At some exposures, a 15 cm bed of oolitic limestone occurs at the top. Uranium minerals occur mainly on joint planes and as the lining of vugs in areas of re-crystallized calcite on the flanks

TABLE 2. Production from mines in the Sanostee area, San Juan County, New Mexico (from unpublished U.S. Department of Energy records, McLemore, 1983). Mines are located on Figure 1. Vanadium grade reported for only 37,289 tons of ore from Enos Johnson 3. The mine identification number (Mine id) is from the New Mexico Mines Database (McLemore et al., 2005a, b).

Mine Id	Mine Name	Geologic Unit	Short Tons Ore	U_3O_8 (lbs.)	U_3O_8 %	V_2O_5 (lbs.)	V_2O_5 (lbs.)	Periods of Production/ Operator(s)
NMSJ0029	Carl Yazzie 1	Jms	23	66	0.15	347	0.76	1954 – Bee-Sho-Shee Mining Co.
NMSJ0030	Castle Tsosie	Jmru	12	60	0.25	19	0.08	1956 – Bee-Sho-Shee Mining Co.
NMSJ0035	Deneh Nezz 1	Jmru	192	654	0.17	1542	0.40	1952-55 – Rogers and Sons
NMSJ0035	Deneh Nezz 2	Jmru	113	327	0.14	700	0.31	1955 – Rogers and Sons
NMSJ0036	Deneh Nezz 3	Jmru	7	55	0.39	58	0.41	1955 – Rogers and Sons
NMSJ0047	Enos Johnson	Jmru	1,544	3629	0.12	4434	0.14	1952 – Enos Johnson Sr. 1952-54 – R. D. Young
NMSJ0047	Enos Johnson 1	Jms	133	265	0.10	343	0.13	1952-53, 1955 – R. D. Young
NMSJ0047	Enos Johnson 2	Jms	143	400	0.14	419	0.14	1952, 1954 – R. D. Young
NMSJ0048	Enos Johnson 3 (South Peak Mine) (Sanostee Mine)	Jmru	136,826	325,906	0.12	96,923	0.13	1952-56 – R. D. Young, 1956 – Shiprock Uranium Corp., 1958-59 – Shiprock Industries, Inc., 1961-64 – A and B Mining Co., 1964-71 – Ray L. Williams, 1976-82 – Ray L. Williams
NMSJ0052	H. B. Roy 2	Jt	6	11	0.10	31	0.28	1954 – Bigler and Johnson
NMSJ0055	Horace Ben	Jmru	4	13	0.17	18	0.24	1952 – Cox and Rogers
NMSJ0058	Joe Ben 1	Jmru	6	42	0.36	49	0.42	1952 – Rogers and Sons
NMSJ0060	Joe Ben 3	Jms	225	946	0.21	3256	0.72	1953, 1955 – Rogers and Sons
NMSJ0061	John Joe 1	Jms	94	243	0.13	739	0.39	1955 – Rogers and Sons
NMSJ0066	Key and Tohe	Jmru	47	90	0.10	261	0.28	1954 – Bee-Sho-Shee Mining Co.
NMSJ0082	Reed Henderson	Jt	24	14	0.03	52	0.11	1954 – Hancock and Hutchison
TOTAL			139,399	332,721	0.12	109,191	0.14	

of the small anticlinal folds, which are 1 to 2 ft high, 3 ft wide, and 10 to 15 ft long. Mineralization also has been reported in the oolitic limestone.

Shipments of uranium ore from the Todilto have been made from the H.B. Roy No. 2 and the Reed Henderson properties in the southern part of the area (Fig. 1). Because the grade of the material from the Reed Henderson prospect averaged less than 0.10% U_3O_8, the minimum the AEC accepted, no payment was made for this material.

AEC reconnaissance found that yellow minerals occur sparsely in the upper 5 ft of the Todilto Limestone at several localities from the Reed Henderson property northward to the Tyler prospect (Fig. 1). No uranium is known in the Todilto limestone in its outcrops in Bear Creek Canyon, north of Figure 1. The AEC mineralogy/petrology lab identified tyuyamunite and metatyuyamunite in Todilto samples from Sanostee, no location given, and Gruner and Smith (1955, p. 36) identified cuprosklodowskite in samples from the Reed Henderson prospect.

Chlorite, hematite, and manganite [MnO(OH)] are commonly associated with the mineralized folds. The small anticlinal folds have a width of about 3 ft, a height of 1 or 2 ft, and a length of 10 or 15 ft. Between anticlines, beds are flat rather than bowed downward. In areas of intense folding the fold axes are from 5 to 20 ft apart. The axes frequently have a common orientation in areas of intense folding, but they do not appear to parallel any of the Laramide structures. The folds are not reflected in the lower portion of the Todilto or in the Summerville Formation above. Mineralization occurs in areas of most intense folding. Coarse-grained calcite is commonly found in the folds. Because the folds are confined to the upper Todilto or in younger rocks, they are presumed to be diagenetic, along with the coarsely crystallized calcite associated with them.

Salt Wash Member of the Morrison Formation

The Salt Wash Member is a fluvial deposit about 50 ft thick in the vicinity of the Enos Johnson No. 3 mine (Fig. 1). Its thickness increases northward to about 140 ft near Red Rock, AZ, 27 km northwest of Sanostee, and thins rapidly southward. The Sanostee area lies on the southeast edge of the Salt Wash depositional fan described by Craig and others (1955) and the sedimentary structures indicate that the direction of paleostream flow was mainly to the southeast. The Salt Wash is an alternating sequence of green and red mudstone and siltstone and light gray and red sandstone. Mudstone and siltstone make up 60 to 75 percent of the Salt Wash exposed in the vicinity of the Enos Johnson No. 3 Mine. The sandstone units are medium-to very fine-grained, poorly sorted, and moderately cemented. Very fine-grained sandstone predominates and some of the arenaceous units contain carbonaceous trash and logs; all have fluvial festoon bedding and current linea-

tion. Uranium occurs in light- to medium-gray sandstone in the upper part of the Salt Wash where it is disseminated as grain coatings and as cement. The mineralization is either directly above or below a mudstone unit or associated with carbonaceous trash and carbonized logs.

Uranium in the Salt Wash has been mined from the Carl Yazzie No. 1, Enos Johnson Nos. 1 and 2, Joe Ben No. 3, and the John Joe No. 1 properties (Fig. 1). Oxidized vanadium minerals, including uranium vanadates, have been found in the Salt Wash as far north as the John Joe No. 2 property (Fig. 1). No uranium in the Salt Wash has been reported south of the Carl Yazzie No. 1 Mine, or in Bear Creek Canyon to the north. The minerals occur in light- to medium-gray sandstone in the upper part of the Salt Wash. The lower portion, which contains a large percentage of siltstone and mudstone, does not contain uranium.

The deposits in the Salt Wash are small, approximately 150 short tons, and have an average grade of about 0.15% U_3O_8, 0.70% V_2O_5, and 15% $CaCO_3$. The deposits have a diameter of 7 to 15 m and are oval-shape with an average thickness of 0.5 m.

Blagbrough and others (1959, p. 17) recognized three types of deposits in the Salt Wash. In one, the minerals are directly above or below a mudstone, in very fine-grained, light-gray sandstone. The mudstone in the vicinity of uranium is altered from normal red to green. The mineralized zone is thin and tabular and parallels the mudstone for 7 to 15 m and ranges in thickness from a few cm to 0.6 m. At places the sandstone fills a scour in the mudstone, and uranium is concentrated in the scour.

A second type of deposit is in a light-gray, very fine-grained sandstone lens rich in carbonaceous trash. The uranium occurs in carbon trash and at places forms a halo around it. The mineralized areas range from a few cm to0.6 m thick and from 7 to 15 m wide. Limonite is typically associated with the carbon-trash type of deposit. A halo of uranium around a carbonized log constitutes the third type of deposit. The logs have diameters of 0.3 to 0.6 m and commonly are 1-1.2 m long. Uranium fills fractures in the logs and is also disseminated in the very fine-grained, light gray sandstone around them.

The Salt Wash ores from throughout the Colorado Plateau are well-known for their high vanadium content. Ores shipped from the nearby Lukachukai and Carrizo Mountains had uranium to vanadium ratios of 1:4 and 1:9, respectively (Chenoweth and Malan, 1973). With the exception of the Carl Yazzie No. 1 mine in the southern part of the area (Fig. 1), where the uranium to vanadium ratio is 1:5, the Salt Wash ores from the Sanostee area were quite low in vanadium.

Recapture Member of the Morrison Formation

The Recapture Member of the Morrison Formation is approximately 160 m thick at the Enos Johnson No. 3 mine (Fig. 1). Thirteen km north of the mine on the north side of Beautiful Mountain, its thickness is approximately 125 m. Sixteen km southwest of Sanostee, at the head of Theodore Wash, 84 m has been measured. The Recapture Member is a fluvial deposit and in the Sanostee area, the member exhibits a rapid facies change. The sandstone-conglomerate facies covers a large area in the south and west, and grades into the sandstone facies to the east and north. The shale facies is north and east of the sandstone facies. Sedimentary structures in the vicinity of the Enos Johnson No. 3 mine in the upper part of the Recapture suggest that the paleostreams were flowing from the southeast.

In the Sanostee area, the Recapture is divided into lower and upper lithologic units (Blagbrough and others, 1959). Locally, the thicknesses of these units vary considerably because the upper unit fills paleostream channels eroded into the lower unit. The lower unit is approximately 91 m thick near the Enos Johnson No. 3 mine where it is exposed as a series of three red sandstone cliffs separated by benches. It consists of red and light gray, coarse- to fine-grained sandstone showing festoon and planar bedding with minor interbedded red siltstone and mudstone. Lower beds contain carbonized fossil logs and fine-grained sand predominates. The contact between the upper and lower units is usually gradational and is based largely on the degree of friability. North of Beautiful Mountain, 13 km north of the Enos Johnson No. 3 mine, the lower unit intertongues with the Salt Wash, and the lower unit is not recognizable north of Red Rock, AZ, 27 km northwest of Sanostee. Fifty seven km south-southwest of the Sanostee area, in the vicinity of Todilto Park, NM, the lower unit intertongues with the Cow Springs Sandstone, and intertonguing between the lower and upper units probably occurs south of the Enos Johnson No. 3 Mine.

The upper Recapture unit is a friable sandstone and typically forms a slope or series of slopes between the more resistant lower unit and the overlying Westwater Canyon Member. The upper unit is approximately 61 m thick and consists of coarse- to very fine-grained, light red to light gray sandstone with minor amounts of interbedded red and green mudstone. The sandstone units have festoon and planar bedding and grade laterally into mudstones and siltstones. The contact between the Recapture and Westwater Canyon Members is generally sharp.

Uranium ore has been shipped from deposits in the lower unit of the Recapture from the Deneh Nezz No. 3 prospect and from the Joe Ben No. 1 prospect on the north side of Sanostee Wash (Fig. 1). These deposits are associated with mineralized fossil logs that occur in the Recapture from 9 to 21 m above the contact with the underlying Salt Wash Member. Mineralized logs also have been found on the David Kee property (Fig. 1) and on the White Cone property, which is located on the west side of Bear Creek Canyon, in Apache County, Arizona. The logs are partly calcified, have a diameter of 0.3 to 1 m and are 1.5 to 4.6 m long. Uranium is in fractures in the logs and also is disseminated through a few meters of the enclosing sandstone. Adjacent to the logs, fine-grained sandstone is altered from red to light-gray. Mineralized areas are as much as 1.2 m in diameter. The deposits in the lower Recapture have a maximum diameter of 6 m, are 0.3 or 0.6 m thick, and contain 5 to 10 short tons of material averaging 0.30% U_3O_8 and 0.30% V_2O_5. The limestone content also is high, because the uranium is closely associated with calcified logs.

The upper unit of the Recapture contains the largest uranium deposits in the Sanostee area. Ore has been shipped from the Horace Ben and Enos Johnson properties on the south side of Sanostee Wash and the Deneh Nezz Nos. 1 and 2, Castle Tsosie,

and Kee and Tohe properties on the north side (Fig. 1). The Enos Johnson No. 3 mine is the largest and highest grade deposit. Uranium in the upper unit of the Recapture occurs from east of the Carl Yazzie mine in the southern part of the area, to the H.B. Roy No. 1 property in Bear Creek Canyon to the north. Most of the uranium in the upper Recapture is confined to a zone of light-gray sandstone with a maximum thickness of 18 m which occurs from 3-52 m below the Recapture Westwater Canyon contact. Mineralized zones are 6-91 m long and a few centimeters to 6 m thick.

Blagbrough and others (1959, p. 18) described two types of uranium occurrences in the upper unit of the Recapture. In the first, uranium occurs above or below a mudstone or siltstone unit in a medium- to fine-grained, light-gray sandstone. The siltstone or mudstone is commonly 0.6-1 m thick and is altered from red to green. The mineralized zone is a few cm to 0.6 m thick and ranges in grade from a trace to as much as 1% U_3O_8. Uranium, is for the most part, fairly continuous along the siltstone or mudstone unit, and some uraniferous zones can be followed for a distance of 91 m. The richest deposits occur along mudstones, which lie unconformably on sandstones; deposits along siltstones are commonly low grade.

The second type of mineralized zone is a few cm to 6 m thick and has a lateral extent of as much as 91 m. The uranium is in a medium- to fine-grained, light-gray, thick sandstone lens and occurs as a halo around limestone concretions that range in diameter from a few cm to 1.8 m. Thin, irregular stringers and pebbles of mudstone and siltstone also have halos of uranium, which are as much as 1 m thick. The mudstones are chiefly red, but siltstones are altered to green. Uranium also is found in sandstone lenses containing red mudstone galls. Where the uranium forms a halo around and impregnates the galls, the mineralization is commonly 0.3 or 0.6 m thick. A thick mudstone or siltstone typically underlies the mineralized sandstones, and the lens is capped with an altered mudstone or siltstone.

The AEC identified carnotite in samples collected from outcrops on the Enos Johnson property. Schroeckingenite was reported by Droullard and Jones (1951), and Gruner and Smith (1955, p. 36) reported uranophane. Other than carnotite, no vanadium minerals have been identified, but some samples contain a higher ratio of vanadium to uranium than is present in carnotite, so that the presence of other vanadium-bearing minerals is indicated. Hematite, chlorite, and limonite are commonly associated with the higher grade deposits, and these minerals in some places mask the color of the carnotite. Chlorite is an ingredient of siltstone in the low-grade deposits. Chlorite, hematite, limonite, and carnotite coat and cement the sand grains.

THE ENOS JOHNSON NO. 3 MINE

This mine has produced more uranium than any other mine in the Sanostee area. It is also known as the South Peak mine and the Sanostee mine. Beginning in 1958, the “No. 3” was dropped from the name as it was the only operating mine on Enos Johnson’s mining permit. The portals of the mine are at an elevation of about 2246 m on the west side of a prominent mesa known as South Peak. When the mine closed in late 1982, the workings had extended some 853 m in an east-northeast direction from the portals. Because the ore bodies generally were parallel to the bedding of the host rock, the working area declined about 12˚ to the east, parallel to the bedding of the host rock. The average width of the mined area is about 91 m. Mining was by modified room and pillar methods. Ore was removed from the mine by small diesel-powered trucks. Radon gas was a problem at the mine, and the declined workings added to the ventilation problems. Radon concentration readings taken by mine inspectors averaged 24.7 working levels in 1954, 12.5 in 1955 and 10.4 in 1967 (U.S. Department of Justice, Radiation Unit, written communication, 2009). Radon, being heavier than air, it tended to accumulate in the deeper parts of the mine.

The sandstone bed containing the Enos Johnson ore bodies appears to be more laterally continuous than other Recapture sandstones. The ore deposit consist of a series of ore bodies separated by mineralized rocks which occur throughout a 6 m-thick zone in the host sandstone. A typical ore body will be 152-183 m long and 46-61 m wide. Ore thicknesses range from 0.3 m to about 6 m of discontinuous mineralization. Ore grades as recorded in monthly ore receipts to the AEC ranged from a high of 0.25% U_3O_8 in the 1950s to 0.06% in the late 1970s, with the average for the mine being 0.12% U_3O_8.

The vanadium content of the Enos Johnson No. 3 ores is quite low compared to ores from the Salt Wash Member. As already mentioned, the Salt Wash deposits at Sanostee also are lower than normal in vanadium. In this respect they resemble the deposits of the Grants district. This could reflect differences in the origin or source between other Salt Wash deposits in the Grants and Sanostee districts. The uranium to vanadium ratios in monthly ore receipts have ranged from 1:1.75 to 1:0.42 for the Enos Johnson No. 3 Mine. The ratio in 7,783 short tons mined during 1952-56 was 1:0.89; in 2,399 short tons mined during 1958-59 the ratio was 1:0.79; and in 8,950 short tons mined in 1960-64 was 1:0.51. These statistics could possibly indicate a systematic decrease in vanadium, as mining progressed down- dip from the outcrop.

Very little is known about the mineralogy of the Enos Johnson No. 3 Mine. Samples of ore collected by Chenoweth in September 1961 from a reddish-brown siltstone were examined by the AEC mineralogy/petrology lab. The lab (personal communication, 1962) found that uranium was disseminated in hematite coatings on quartz grains. Green and others (1982, p. 17) of the U.S. Geological Survey reported coffinite in samples of dark black ore, and the association of uranium with hematite in reddish ores. Analyses of several ore samples collected by Chenoweth indicated that chemical U_3O_8 exceeded the radiometric U_3O_8 by 25 to 30%. This would indicate that the uranium in the deposit is still migrating due to the lack of sufficient vanadium to fix it.

URANIUM RESOURCE POTENTIAL

It is likely that additional small deposits could occur in the Sanostee district. However, the Navajo Indian Tribe has a moratorium on any uranium exploration and mining within the boundaries of the reservation. Furthermore, the known deposits in the Sanostee district were relatively small compared to the larger

more extensive deposits in the Grants district. It is unlikely that any of the deposits in the Sanostee district will be mined in the foreseeable future.

SUMMARY

During the period 1952 through 1982, the large underground mine on Enos Johnson's mining permit, west of the village of Sanostee, produced 136,665 short tons of ore that averaged 0.12% U_3O_8containing 325,927 pounds of U_3O_8. Ores that were analyzed for vanadium averaged 0.14% V_2O_5 (Table 1). This production makes the Enos Johnson mine the largest uranium mine in New Mexico, outside the Grants mineral belt (McLemore, 1983).

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