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Selenium Occurrence in Certain Soils in the United States, with a Discussion of Related Topics: Seventh Report[1,2]

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SUMMARY

This report presents as its chief topics the results of a survey of selenium occurrence in North Dakota and of a reconnaissance examination of parts of Oregon, Idaho, Nevada, and Utah, where the absorption of the element by plants fed on by livestock has caused selenium poisoning. Included also are data on selenium distribution in slimes deposited in Silver Creek from the mining operations at Park City, Utah.

A large part of the glacial drift overlying northwestern North Dakota has been shown to contain sufficient selenium to produce seleniferous soil. Likewise, the lacustrine beds of ancient glacial lakes in this area are frequently seleniferous. The possibility of occasional seleniferous areas of small extent in the glacial drift of eastern North Dakota was studied and a few examples of such areas are described.

[1] Submitted for publication April 17, 1942. Suspended by wartime restrictions and resubmitted May 13, 1946.

[2] The previous reports on this subject—one to six, respectively—are contained in Technical Bulletins Nos. 482, 530, 601, 702, 758, and 783.

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The selenium content of samples taken near the junction of the Niobrara and Pierre formation of Cretaceous age in northeastern North Dakota was determined and compared with analyses of similar material taken at other points over an area extending 800 miles to the south. A remarkably constant selenium content of 10 to 30 parts per million was observed.

Results are reported of a reconnaissance survey of parts of Utah, Nevada, Idaho, and Oregon, together with data obtained on materials from these States received from other sources.

The finding of a seleniferous area in eastern Oregon was the first indication that there were seleniferous soils in that State. The known area of such soils derived from the Payette deposits was extended both eastward and westward along the Snake River. An exposure of Cretaceous shales of low selenium content was found in eastern Idaho. Data were obtained on the existence of small areas of mildly seleniferous soils in alluvial material in Utah and Nevada.

PREVIOUS INVESTIGATIONS

A livestock disorder that occurs in the semiarid Great Plains of the United States has been known and described for many years. This disorder, selenium poisoning, is caused by the ingestion of vegetation that has absorbed this toxic element from the soil (*2, 6, 11, 12, 15, 20, 22, 25*).[3] For several years the Division of Soil Chemistry and Physics [4] has interested itself in an investigation of the occurrence and distribution of selenium in soils and vegetation, and related topics. The results of these studies have been published in a considerable number of bulletins and miscellaneous papers, some of which are listed in the literature cited (*6, 7, 10, 16, 17, 23, 33, 34*).

Among other things, the fact has been demonstrated that selenium is widely distributed and is probably present in all soils; also, that it is present in many thousand square miles of soils in sufficient concentration to render some vegetation toxic to animals. The term "seleniferous soils" is properly applied only to areas capable of producing some vegetation that is toxic because of the selenium. The distinction is important because the form of selenium in the soil appears to play as large a role in its absorption by plants as does its quantity.

It was early shown (*6, 7*) that there is a definite relation between the seleniferous character of the soils and the geological formation that furnishes their parent material, and that, for the most part, seleniferous soils were derived from Cretaceous formations, particularly from the Pierre and Niobrara formations of Upper Cretaceous age (*6*). Based on this knowledge, geological maps have proved to be useful guides in locating seleniferous areas in Nebraska, Kansas, New Mexico, Wyoming, Montana, and Canada. All areas of soils derived from material of Cretaceous age may contain harmful quantities of selenium, but not all such areas are seriously affected; the Cretaceous shales of California and the Cretaceous beds of New Jersey and Maryland, for example, have been shown to be free of any widespread exposure of high selenium content (*17*).

[3] Italic numbers in parentheses refer to Literature Cited, p. 35.

[4] Now a part of the Division of Soil Management and Irrigation.

Another valuable aid in locating seleniferous areas is found in indicator plants. These are plants that appear to require selenium for their normal growth (*19, 27, 28, 29*). As a consequence, their occurrence in a given area is an indication of the possible presence of injurious quantities of selenium. Among indicator plants of wide occurrence are *Astragalus pectinatus* Dougl., *A. bisulcatus* A. Gray, *A. racemosus* Pursh, and *Stanleya pinnata* (Pursh) Britton. Largely through the use of these plants as guides, areas of seleniferous soils have been located in Montana (*33*), North Dakota (*34*), Nevada (*17*), and Idaho (*34*), and in the Canadian Provinces of Alberta, Saskatchewan, and Manitoba (*9, 34*). Beath, Gilbert, and Eppson (*3, 4, 5*) have made use of these plants in locating seleniferous areas in Wyoming also, as well as in many other States. Both geological maps and indicator plants were used as aids in the work presented in this report. The methods of analysis used to determine the selenium content of the various materials reported have been previously described (*24, 32*).

SELENIUM SURVEY IN NORTH DAKOTA

Early in the summer of 1938 the writers made a reconnaissance examination of Burke, Mountrail, Ward, and Williams Counties, N. Dak., during which 34 samples of soil, shale, and vegetation were collected at 13 stations. The selenium content of the 12 samples of soil ranged from 0.5 to 2 parts per million (p. p. m.). The 9 samples of *Astragalus pectinatus* ranged in selenium content from 280 to 1,660 p. p. m., and 6 samples of *A. bisulcatus* contained 60 to 470 p. p. m. (*34*).

Later in the same season 85 samples of wheat and 20 of rye, barley, oats, and flaxseed were obtained from grain elevators, freight cars, and flour mills in North Dakota. Thirty-two of these contained 1 to 2 p. p. m. of selenium (*34*). When composite samples of commercial grain show a selenium content of 2 p. p. m., one may reasonably suspect that some fields in the area produce toxic grain.

These data indicate a continuation of the seleniferous area in Montana eastward into North Dakota to a distance of at least 100 miles east of the Montana border. Also, a marked similarity in origin and seleniferous character is indicated between the soils in this part of North Dakota and those northward in Saskatchewan, Canada. Further investigation of this area appeared warranted.

It was not until the spring of 1940 that opportunity was afforded to examine the area in northwestern North Dakota in greater detail. At that time samples of soil and vegetation were taken at approximately 10-mile intervals along north-south transects, 5 to 8 miles apart, throughout the area bounded by the Missouri River on the south, the eastern limits of Bottineau, McHenry, and McLean Counties on the east, the Canadian border on the north, and Montana on the west. A few samples of soils and shales were collected at two exposures of Pierre and Niobrara shales in Cavalier County in the northeastern part of the State. Also, a few samples were collected at points outside the area where *Astragalus bisulcatus* was observed.

A considerable part of the area examined is covered by soil derived from glacial drift. In the breaks to streams, the underlying Fort

Union formation of the Eocene series is frequently exposed west of Minot. The Pierre shale of Upper Cretaceous age is overlain by glacial drift and lacustrine material in Bottineau and McHenry Counties, but this shale is not known to be exposed in either of these counties. Both Fort Union (*34*) and the Pierre formations (*7*, *8*) have been previously shown to be seleniferous. Although the seleniferous soils of this area are derived largely from glacial drift and lacustrine material, it appears that these materials are largely of Fort Union and Pierre origin.

In this survey, soils were examined only where external indications of the presence of selenium were observed. *Astragalus pectinatus* and *A. bisulcatus* are common to much of the area and were the guides used in making the collections.

The data on the 324 samples of soils, minerals, and vegetation collected for selenium analysis are given in table 1.

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*

BOTTINEAU COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26882	117	11 miles northeast of Loraine, on road to Antler.	Brown silt loam, 0–10 inches	2.4	
B26883	117A	do	*Astragalus bisulcatus*		710
B26884	118	2½ miles southeast of Kuroki, on road to Westhope.	Grayish-brown sandy loam, 0–10 inches.	3	
B26885	118A	do	*A. bisulcatus*		4,400
B26886	119	3 miles south of Westhope, on U. S. No. 83.	Grayish-brown loam, 0–10 inches.	1.6	
B26887	119A	do	*A. bisulcatus*		2,620
B26888	119B	do	Young wheat 4–5 inches tall, 60 feet from 119.		90
B26889	120	18 miles southwest of Westhope, on U. S. No. 83.	Brown silt loam, 0–10 inches	3	
B26890	120A	do	*A. bisulcatus*		1,150
B26891	121	30 miles south-southwest of Westhope, on U. S. No. 83.	Dark-brown silt loam, 0–10 inches.	1	
B26892	121	do	Brown clay loam, 20–30 inches	4	
B26893	121A	do	Young wheat 3–4 inches tall, growing in and adjacent to B26891.		8
B26894	121B	do	*A. pectinatus* growing in B26892		2,590
B26910	128	12 miles northeast of Wolseth, on road to Eckman.	Brown sandy loam, 0–12 inches	.6	
B26911	128A	do	*A. bisulcatus*		320
B26912	129	3 miles east of Dunning, on road to Newburg.	Brown sandy loam, 0–10 inches	2	
B26913	129A	do	*A. bisulcatus*		3,070
B26914	129B	do	Young wheat 3–4 inches tall, 75 feet from B26912.		140
B26915	130	5 miles north of Newburg, on road to Landa.	Dark-brown loam, 0–10 inches	2	
B26916	130A	do	*A. pectinatus*		1,070
B26917	130B	do	Young wheat 3–4 inches tall, 3–5 feet of soil.		60
B26918	131	4 miles east of Landa, on road to Roth.	Brown loam, 0–10 inches	.8	
B26919	131A	do	*A. bisulcatus*		760
B26920	132	5 miles east of Roth, on road to Souris.	Gray clay loam, 0–10 inches	1.2	
B26921	132A	do	*A. bisulcatus*		270
B26922	133	1 mile south of Carbury, on State Road 14.	Brown loam, 0–10 inches	.8	
B26923	133A	do	*A. bisulcatus*		810

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

BOTTINEAU COUNTY—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26924	134	12 miles east of Bottineau, at county line.	Dark-gray silt loam, 0–10 inches	1	
B26925	134A	do	Young wheat 3–5 inches tall, within 6 feet of soil.		60
B26926	135	1 mile east of Bottineau, on State Road 5.	Brown loam, 0–10 inches	2	
B26927	135A	do	*A. bisulcatus*		510
B26928	135B	do	Young wheat 4–5 inches tall, within 6 feet of soil.		60
B26929	136	9 miles west of Bottineau, on State Road 5.	Brown loam, 0–10 inches	2	
B26930	136A	do	*A. bisulcatus*		870
B26931	136B	do	Young wheat 5–6 inches tall, 4 feet of soil.		70
		BURKE COUNTY			
B26704	37	North edge of Larson	Brown silt loam, 0–10 inches	1	
B26705	37A	do	*A. pectinatus*		1,840
B26706	38	9 miles south of Columbus, on State Road 40.	Light brown clay loam, 0–10 inches.	1.4	
B26707	38A	do	*A. pectinatus*		1,670
B26708	40	19 miles south of Columbus, on State Road 40.	Brown silt loam, 0–10 inches	1.4	
B26709	40A	do	*A. pectinatus*		3,860
B26718	45	19 miles north of Stanley, on State Road 8.	Brown clay loam, 0–10 inches	1.2	
B26719	45A	do	*A. pectinatus*		280
B26720	46	30 miles north of Stanley, on State Road 8.	Brown silt loam, 0–10 inches	1.6	
B26721	46A	do	*A. pectinatus*		600
B26722	47	5½ miles northeast of Coteau, on State Road 8.	Brown silt loam, 0–10 inches	1.2	
B26723	47A	do	*A. pectinatus*		2,570
B26724	48	1 mile south of Canadian line, on State Road 8.	Brown silt loam, 0–10 inches	1	
B26725	48A	do	*A. pectinatus*		320
B26738	53	1/4 mile east of Powers Lake	Brown silt loam, 0–10 inches	1	
B26739	53A	do	*A. pectinatus*		3,830
B26740	54	9 miles northeast of Powers Lake, on road to Lignite.	Brown silt loam, 0–10 inches	1	
B26741	54A	do	*A. pectinatus*		2,580
B26742	55	20 miles north of Powers Lake, on road to Lignite.	Brown silt loam, 0–10 inches	1.2	
B26743	55A	do	*A. pectinatus*		1,870
B26744	55B	do	Young wheat, 3–5 inches tall		30
		CAVALIER COUNTY			
B26415	1W	Mayo Brick & Tile Co. pit, at junction of Pembina and Little Pembina Rivers.	Dark-gray thin-bedded shale (Benton?).	16	
B26416	1X	do	Mottled yellow and gray shale	1.6	
B26417	1A	do	*Astragalus* sp. (between 1W and 1X).		1,660
B26418	1	do	Dark-gray clay 0–12 inches (200 yards from pit).	1.6	
B26419	1Z	do	Yellow shale near top of hill	1.4	
B26420	2V	Workings of former Northern Cement & Plaster Co., on Olson farm, 2 miles southwest of Concrete.	Bentonite 4 feet above 2X (Pierre formation).	1.6	
B26421	2W	do	Fissile shale immediately above 2X (Pierre formation).	32	
B26422	2X	do	Limonite layer at junction of Pierre and Niobrara formations.	34	
B26423	2Y	do	Nodule in Niobrara 6 inches below 2X.	36	
B26424	2Z	do	"Cement rock," 5 feet below 2X (Niobrara formation).	14	
B26425	2XZ	do	Yellow seam 3 inches thick immediately below 2Z.	28	

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

DICKEY COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26934	138	11 miles north of Ellendale, on U. S. No. 281.	Dark-brown loam, 0–10 inches	0.8	
B26935	138	do	Light-brown clay loam, 48–60 inches.	.6	
B26936	138A	do	Young barley, 4–5 inches tall, 2 feet of B26934.		15
B26937	138B	do	*A. bisulcatus*, growing in B26935		570

DIVIDE COUNTY

B26639	6	11 miles north of county line, on U. S. No. 85.	Brown clay, 3–3½ feet	0.6	
B26640	6A	do	*A. pectinatus*		1,880
B26641	7	1 mile east of Fortuna, on U. S. No. 85A.	Brown silt loam, 0–10 inches	1	
B26642	7A	do	*A. pectinatus*		1,280
B26643	8	½ mile south of Canadian line, on U. S. No. 85A.	Grayish-brown mottled clay, 6–6½ feet.	1.2	
B26644	8A	do	*A. bisulcatus* (?)		160
B26645	9	2 miles south of Alkabo, on road to Grenora.	Brown silt loam, 0–10 inches	.8	
B26646	9A	do	*A. pectinatus*		1,200
B26647	10	10 miles south of Alkabo, on road to Grenora.	Brown silt loam, 0–12 inches	.1	
B26648	10A	do	*A. pectinatus*		570
B26649	11	17 miles south of Alkabo, on road to Grenora.	Grayish-brown silt loam, 0–10 inches.	1	
B26650	11A	do	*A. pectinatus*		2,000
B26669	21	6 miles north of Alamo	Light-brown silt loam, 0–10 inches.	.6	
B26670	21A	do	*A. pectinatus*		1,780
B26671	21B	do	Young wheat, 3 inches tall		20
B26677	24	2 miles north of Corinth, on State Road 42.	Light-brown gravelly loam, 0–10 inches.	.6	
B26678	24A	do	*A. pectinatus*		2,760
B26679	25	14 miles north of Corinth, on State Road 42.	Light-brown silt loam, 0–10 inches.	.4	
B26680	25A	do	*A. pectinatus*		3,560
B26681	26	2 miles south of Canadian border, on State Road 42.	Light-brown silt loam, 12–24 inches.	.8	
B26682	26A	do	*A. pectinatus*		4,740
B26683	27	9 miles west of Crosby, on State Road 5.	Gray clay loam, 24–36 inches	.4	
B26684	27A	do	*A. pectinatus*		820
B26685	28	½ mile south of State Road 5, on road to Wildrose.	Brown loam, 0–10 inches	.6	
B26686	28A	do	*A. pectinatus*		2,100
B26687	29	1 mile northwest of Wildrose	Brown silt loam, 0–10 inches	.8	
B26688	29A	do	*A. pectinatus*		3,000
B26698	34	7 miles north of McGregor, on road to Noonan.	Grayish-brown silt loam, 0–10 inches.	1	
B26699	34A	do	*A. pectinatus*		3,300
B26700	35	17 miles north of McGregor, on road to Noonan.	Brown silt loam, 0–10 inches	.6	
B26701	35A	do	*A. pectinatus*		310
B26702	36	4½ miles north of Noonan on State Road 40.	Brown silt loam, 0–10 inches	.6	
B26703	36A	do	*A. pectinatus*		1,470

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

McHENRY COUNTY

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26859	108	7 miles north of Ruso, on State Road 41.	Brown silt loam, 0–10 inches	1	
B26860	108	do	Light-brown clay loam, 30–40 inches.	1.6	
B26861	108A	do	Young wheat, 3–4 inches tall, within 4 feet of B26859.		35
B26862	108B	do	*A. bisulcatus*, growing in B26860		1,980
B26863	109	1 mile southeast of Norwich, on U. S. No. 2.	Brown silt loam, 0–10 inches	1.4	
B26864	109A	do	*A. bisulcatus*		360
B26865	109B	do	Young wheat, 3–4 inches tall, 2–6 feet of soil.		70
B26868	111	1½ miles northeast of Simcoe, on road to Granville.	Brown silt loam, 0–10 inches	.8	
B26869	111A	do	*A. bisulcatus*		1,130
B26902	125	2 miles east of Deering, on road to Granville.	Brown silt loam, 0–10 inches	1.4	
B26903	125A	do	Mixed grasses in and near B26902.		70
B26904	125B	do	*A. bisulcatus*, in ditch 20 feet from B26902.		2,030
B26905	126	10 miles east of Deering, on road to Granville.	Gray fine sandy loam, 0–10 inches.	.4	
B26906	126A	do	Young wheat, 3–4 inches tall		60

McKENZIE COUNTY

B26628	90	South side of Missouri River on State Road 58.	Pyrites from Fort Union formation.	10	

McLEAN COUNTY

B26770	68	17 miles south of Parshall, on State Road 8.	Mottled gray clay, 60–70 inches (Fort Union).	0.4	
B26771	68A	do	*A. pectinatus*		1,590
B26772	69	3 miles east of Elbowoods, on road to Blackwater.	Dark-brown silt loam, 0–10 inches.	.8	
B26773	69A	do	*A. caryocarpus*		120
B26775	70	17 miles east of Elbowoods, on road to Blackwater.	Mottled gray clay, 20–30 inches (Fort Union).	.4	
B26776	70A	do	*A. bisulcatus*		510
B26777	71	3 miles north of Blackwater, on road to Roseglen.	Brown silt loam, 0–10 inches	1.4	
B26778	71A	do	*A. pectinatus*		1,200
B26779	72	2½ miles west of Roseglen, on road to Raub.	Brown silt loam, 0–10 inches	.8	
B26780	72A	do	*A. pectinatus*		2,630
B26781	73	10 miles northwest of Roseglen, on road to Plaza.	Brown clay loam	1	
B26782	73A	do	*A. pectinatus*		4,950
B26831	96	5 miles south of Ryder, on State Road 28.	Light-brown clay loam, 30–40 inches.	.6	
B26832	96A	do	*A. pectinatus*		340
B26833	97	2 miles north of Garrison, on road to Douglas.	Brown silt loam, 0–10 inches	.8	
B26834	97A	do	Young wheat, 3–4 inches tall		40
B26835	98	4 miles north of Garrison, on road to Douglas.	Dark grayish-brown clay, 0–10 inches.	.8	
B26836	98A	do	*A. bisulcatus*		650
B26848	104	28 miles south of Minot, on U. S. No. 83.	Brown silt loam, 0–10 inches	2	
B26849	104A	do	*A. pectinatus*		2,260

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

McLEAN COUNTY—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26850	105	6 miles south of Max, on U. S. No. 83.	Grayish-brown clay, 30-40 inches.	0.6	
B26851	105A	do	*A. pectinatus*		2,240
B26852	106	9 miles east of Garrison, on road to Crooked Lake.	Brown silt loam, 0-10 inches	1.2	
B26853	106	do	Mottled grayish-brown clay, 60-70 inches.	1	
B26854	106A	do	Young wheat, growing in and adjacent to surface soil.		120
B26855	106B	do	*A. pectinatus*, growing in B26853		2,880
B26856	107	11 miles north of Turtle Lake, on State Road 41.	Brown clay loam, 0-12 inches	1.6	
B26857	107A	do	*A. bisulcatus*		2,620
B26858	107B	do	*A. caryocarpus*, 15 feet from B26856.		30
B26870	112	16 miles south of Butte, on road to Mercer.	Mottled gray clay, 0-10 inches	.6	
B26871	112A	do	*A. bisulcatus*		70

MOUNTRAIL COUNTY

B26710	41	2½ miles south of Battleview, on road to White Earth.	Brown clay loam, 0-12 inches	0.8	
B26711	41A	do	*A. pectinatus*		1,270
B26712	42	13 miles south of Battleview, on road to White Earth.	Brown silt loam, 0-10 inches	1	
B26713	42A	do	*A. pectinatus*		1,070
B26714	43	1.7 miles north of Stanley, on State Road 8.	Brown silt loam, 0-10 inches	3	
B26715	43A	do	*A. pectinatus*		3,160
B26716	44	11½ miles north of Stanley, on State Road 8.	Brown silt loam, 0-10 inches	1	
B26717	44A	do	*A. pectinatus*		1,330
B26734	51	5 miles south of U. S. 2; 1 mile east of Williams County line.	Brown silt loam, 0-10 inches	.6	
B26735	51A	do	*A. pectinatus*		590
B26736	52	3½ miles north of Manitou, on road to Powers Lake.	Brown silt loam, 0-10 inches	.8	
B26737	52A	do	*A. pectinatus*		2,190
B26748	57	10½ miles south of Niobe, on road to Palermo.	Light-brown clay loam, 30-40 inches.	.6	
B26749	57A	do	*A. pectinatus*		2,880
B26750	58	20 miles south of Niobe, on road to Palermo.	Brown silt loam, 0-10 inches	.6	
B26751	58A	do	*A. pectinatus*		2,720
B26752	59	3 miles south of Ross, on road to Sanish.	Mottled gray clay, 60-72 inches	.4	
B26753	59A	do	*A. pectinatus*		850
B26754	60	18 miles south of Ross, on road to Sanish.	Light-brown sandy loam, 0-10 inches.	1.4	
B26755	60A	do	*A. pectinatus*		3,720
B26756	61	3/10 mile east of Sanish, on State Road 23.	Light-brown sandy loam, 0-10 inches.	2	
B26757	61A	do	*A. pectinatus*		2,240
B26758	62	10 miles north of Van Hook, on State Road 8.	Brown silt loam, 0-10 inches	7	
B26759	62A	do	*A. pectinatus*		2,970
B26760	63	21 miles north of Van Hook, on State Road 8.	Light-brown clay loam, 0-10 inches.	.8	
B26761	63A	do	*A. pectinatus*		1,520
B26762	64	3 miles south of Palermo, on road to Parshall.	Brown silt loam, 0-10 inches	5	
B26763	64A	do	*A. pectinatus*		2,560
B26764	65	14 miles south of Palermo, on road to Parshall.	Brown silt loam, 0-10 inches	1	
B26765	65A	do	*A. pectinatus*		1,410
B26765A	65B	do	Young wheat, 5-7 inches tall		30

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

MOUNTRAIL COUNTY—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26766	66	23 miles south of Palermo, on road to Parshall.	Brown silt loam, 0–10 inches	1.4	
B26767	66A	do	*A. pectinatus*		1,100
B26768	67	5 miles south of Parshall, on State Road 8.	Brown silt loam, 0–10 inches	1.2	
B26769	67A	do	*A. pectinatus*		2,310
B26783	74	3/10 mile north of Wabek, on road to Plaza.	Brown silt loam, 0–10 inches	.8	
B26784	74A	do	*A. pectinatus*		3,100
B26785	75	10 miles northwest of Plaza (SE¼ sec. 12, T. 153 N., R. 89 W.).	Brown silt loam, 0–10 inches	8	
B26786	75A	do	*A. pectinatus*		3,600
B26787	75B	do	Mixed grasses		130
B26788	76A	10 miles northwest of Plaza (SW¼ sec. 24, T. 153 N., R. 89 W.).	Oats, 1939 crop		7
B26789	76B	do	Oats, threshing trash		30
B26790	76C	10 miles northwest of Plaza (SE¼ sec. 14, T. 153 N., R. 89 W.).	Barley, 1939 crop		2
B26791	77	6½ miles north of Plaza, on road to Blaisdell.	Brown silt loam, 0–10 inches	.8	
B26792	77A	do	*A. pectinatus*		1,600
B26793	78	18 miles north of Plaza, on road to Blaisdell.	Light-brown loam, 0–10 inches	.8	
B26794	78A	do	*A. pectinatus*		2,510
B26795	78B	do	Young wheat, 3–4 inches tall, 30 feet from No. 78.		30
B26796	79	½ mile northeast of Blaisdell, on U. S. No. 2.	Brown clay loam, 0–10 inches	.4	
B26797	79A	do	*A. pectinatus*		190
B26798	80	12 miles northeast of Blaisdell, on road to Coulee.	Dark-brown clay loam, 0–12 inches.	.4	
B26799	80A	do	*A. bisulcatus*		250

PIERCE COUNTY

B26932	137	At Balta, on State Road 3	Light-brown clay loam, 18–30 inches.	0.5	
B26933	137A	do	*A. bisulcatus*		720

RENVILLE COUNTY

B26802	82	In Norma	Brown loam, 0–10 inches	0.6	
B26803	82A	do	*A. bisulcatus*		150
B26804	83	6 miles northeast of Tolley, on State Road 5.	Light-brown clay loam, 0–10 inches.	1	
B26805	83A	do	*A. pectinatus*		940
B26806	84	4 miles north of intersection of State Road 5, on State Road 28.	Brown silt loam, 0–10 inches	1	
B26807	84A	do	*A. bisulcatus*		220
B26808	85	100 yards south of Canadian border, on State Road 28.	Brown silt loam, 0–10 inches	.2	
B26809	85A	do	*A. bisulcatus*		640
B26810	86	21 miles south of Sherwood, on State Road 28.	Mottled gray clay loam, 10–20 inches.	.2	
B26811	86A	do	*A. bisulcatus*		110
B26812	87	10 miles south of Greene, on State Road 28.	Light-brown clay loam, 20–30 inches.	.2	
B26813	87A	do	*A. pectinatus*		960

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

RENVILLE COUNTY—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26874	114	12½ miles northeast of Foxholm on road to Mohall.	Brown silt loam, 0–10 inches	1.6	
B26875	114A	do	*A. bisulcatus*		1,520
B26876	114B	do	Young wheat		130
B26877	115	28 miles north of Foxholm, on road to Mohall.	Brown loam, 0–10 inches	1	
B26878	115A	do	*A. bisulcatus*		420
B26879	116	5 miles north of Mohall, on road to Loraine.	Brown silt loam, 0–10 inches	2	
B26880	116A	do	*A. bisulcatus*		1,280
B26881	116B	do	Young wheat, 3–4 inches tall, 15–18 feet from B26879.		80

SHERIDAN COUNTY

B26872	113	4 miles east of Mercer, on State Road 7.	Mottled gray clay, 6–7 feet	0.8	
B26873	113A	do	*A. bisulcatus*		620

WARD COUNTY

B26745	56	7 miles west of Kenmare, on road to Niobe.	Brown silt loam, 0–10 inches	1	
B26746	56A	do	*A. pectinatus*		1,140
B26747	56B	do	Winter rye, 5–7 inches tall		50
B27003	2	West slope to Upper Lake, Deslacs Refuge, 1 mile north of Kenmare.	Gray sandy clay, 0–8 inches	1	
B27004	2A	do	*A. bisulcatus*		80
B27005	2B	do	Ripe crested wheatgrass heads		1
B26800	81	1 mile east of Coulee, on State Road 50.	Gray clay, 15 feet (Fort Union)	.6	
B26801	81A	do	*A. bisulcatus*		300
B26814	88	6 miles south of Carpio, on State Road 28.	Brown silt loam, 0–10 inches	.8	
B26815	88A	do	Winter rye, 5–7 inches tall		15
B26816	89	4 miles south of Berthold, on road to Makoti.	Brown silt loam, 0–10 inches	.6	
B26817	89A	do	*A. pectinatus*		1,040
B26818	90	14 miles south of Berthold, on road to Makoti.	Brown silt loam, 0–10 inches	1	
B26819	90A	do	*A. pectinatus*		1,870
B26820	91	24 miles south of Berthold, on road to Makoti.	Brown silt loam, 0–10 inches	2	
B26821	91A	do	*A. pectinatus*		3,190
B26822	91B	do	Young wheat, 3–4 inches tall		30
B26823	92	4½ miles south of Makoti, on road to Roseglen.	Brown silt loam, 0–10 inches	.4	
B26824	92A	do	*A. pectinatus*		1,350
B26825	93	3 miles south of Deslacs, on road to Ryder.	Brown silt loam, 0–10 inches	.6	
B26826	93A	do	Winter rye, 6–7 inches tall, within 3 feet of soil.		30
B26827	94	15 miles southwest of Deslacs, on road to Ryder.	Brown silt loam, 0–10 inches	.8	
B26828	94A	do	*A. pectinatus*		1,840
B26829	95	24 miles south-southwest of Deslacs, on road to Ryder.	Brown silt loam, 0–10 inches	.6	
B26830	95A	do	*A. pectinatus*		1,630
B26837	99	13 miles north of Garrison, on road to Douglas.	Light-brown clay, 0–12 inches	.6	
B26838	99A	do	*A. pectinatus*		2,030

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

WARD COUNTY—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P.p.m.	*P.p.m.*
B26839	100	4 miles north of Douglas, on State Road 23.	Light-brown clay loam, 10–20 inches.	0.4	
B26840	100A	do	*A. pectinatus*		2,280
B26841	100B	do	*Astragalus* sp.		90
B26842	101	15 miles north of Douglas, on road to Drady.	Brown silt loam, 0–10 inches	3	
B26843	101A	do	*A. pectinatus*		140
B26844	102	12 miles south of Minot, on U. S. No. 83.	Dark-brown silt loam, 0–10 inches	1	
B26845	102A	do	*A. caryocarpus*		40
B26846	103	22 miles south of Minot, on U.S. No. 83.	Gray sandy clay, 0–15 inches	.2	
B26847	103A	do	*A. bisulcatus*		160
B26866	110	1.3 miles west of Surrey, on U. S. No. 2.	Light-brown clay loam, 10–20 inches.	.6	
B26867	110A	do	*A. bisulcatus*		1,730
B26895	122	42 miles south of Westhope, on U. S. No. 83.	Light-brown clay loam, 10–20 inches.	2	
B26896	122A	do	*A. pectinatus*		2,370
B26897	122B	do	Winter rye, 3–10 inches tall, within 3 feet of soil.		40
B26898	123	52 miles south of Westhope, on U. S. No. 83.	Brown loam, 0–10 inches	2.4	
B26899	123A	do	*A. bisulcatus*		280
B26900	124	8 miles north of Surrey, on road to Wolseth.	Brown silt loam, 0–10 inches	.4	
B26901	124A	do	*A. bisulcatus*		1,470
B26907	127	2 miles north of Wolseth, on road to Maxbass.	Brown silt loam, 0–10 inches	1	
B26908	127A	do	*A. bisulcatus*		1,600
B26909	127B	do	Young wheat, 4–5 inches tall		70

WILLIAMS COUNTY

B26629	1	1 mile north of Todd	Brown clay loam, 0–10 inches	0.6	
B26630	1A	do	*A. pectinatus*		3,900
B26631	2	4 miles north of Williston, on U. S. No. 85.	Brown loam, 0–10 inches	3	
B26632	2A	do	*A. pectinatus*		3,450
B26633	3	9 miles north of Williston, on U. S. No. 85.	Yellowish-brown clay loam, 0–12 inches.	.4	
B26634	3A	do	*Astragalus* sp.		90
B26635	4	20 miles north of Williston, on U. S. No. 85.	Grayish-brown loam, 0–10 inches	.8	
B26636	4A	do	*A. pectinatus*		1,150
B26637	5	2 miles north of Zahl, on U. S. No. 85.	Yellowish-brown loam, 0–10 inches.	.6	
B26638	5A	do	*A. pectinatus*		3,020
B26651	12	1 mile south of Grenora, on road to U. S. No. 2.	Brown gravelly loam, 0–10 inches.	.4	
B26652	12A	do	*A. pectinatus*		820
B26653	13	22 miles south of Grenora, on road to U. S. No. 2.	Light-brown loam, 0–10 inches	.4	
B26654	13A	do	*A. pectinatus*		1,560
B26655	14	½ mile north of U. S. 2, on road to Grenora.	Light-brown loam, 3–3½ feet	.4	
B26656	14A	do	*A. pectinatus*		2,340
B26657	15	6 miles east of Williston, on road to Sanish.	Gray-mottled clay, 0–10 inches (Fort Union).	1	
B26658	15A	do	*A. pectinatus*		1,280
B26659	16	16 miles east of Williston, on road to Sanish.	Grayish-brown clay loam, 0–10 inches.	1.6	
B26660	16A	do	*A. pectinatus*		3,170
B26661	17	9½ miles south of Wheelock	Light-brown clay loam, 2–2½ feet.	.6	
B26662	17A	do	*A. pectinatus*		520

TABLE 1.—*Selenium content of soils, minerals, and vegetation from North Dakota*—Continued

WILLIAMS COUNTY—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil and minerals	Vegetation
				P. p. m.	*P. p. m.*
B26663	18	1 mile south of Epping	Gray silt loam, 0–10 inches	1	
B26664	18A	do	*A. pectinatus*		1,400
B26665	19	1 mile northwest of Spring Brook, on way to Alamo.	Grayish-brown clay loam, 0–10 inches.	.4	
B26666	19A	do	*A. pectinatus*		1,700
B26667	20	15 miles north of Spring Brook, on road to Alamo.	Grayish-brown silt loam, 0–10 inches.	1.4	
B26668	20A	do	*A. pectinatus*		3,240
B26672	22	5 miles north of Epping, on road to Crosby.	Grayish-brown silt loam, 0–10 inches.	1	
B26673	22A	do	*A. pectinatus*		1,460
B26674	22B	do	Young wheat, 3 inches tall		35
B26675	23	18 miles north of Epping, on road to Crosby.	Grayish-brown silt loam, 0–10 inches.	.6	
B26676	23A	do	*A. pectinatus*		1,640
B26689	30	11 miles south of Wildrose, on road to Ray.	Brown silt loam, 0–10 inches	2	
B26690	30A	do	*A. pectinatus*		2,420
B26691	30B	do	Winter rye, 6 inches tall		20
B26692	31	North edge of Ray	Grayish-brown silt loam, 0–10 inches.	3	
B26693	31A	do	*A. pectinatus*		3,990
B26694	32	½ mile north of Tioga, on State Road 40.	Gray-mottled clay, 60–72 inches	1.2	
B26695	32A	do	*A. pectinatus*		1,460
B26696	33	12 miles north of Tioga, on State Road 40.	Grayish-brown clay, 0–12 inches	.6	
B26697	33A	do	*A. bisulcatus*(?)		110
B26726	49	9½ miles southeast of Ray, on road to Hofflund.	Light-brown silt loam, 0–10 inches.	1.2	
B26727	49A	do	*A. pectinatus*		2,680
B26728	50	3½ miles north of Hofflund, on road to Tioga.	Light-brown silt loam, 0–10 inches.	8	
B26729	50A	do	*A. pectinatus*		3,110
B26730	R50	14½ miles north of Hofflund, on road to Tioga.	Dark-brown silt loam, 0–10 inches.	2.4	
B26731	R50	do	Light-brown silt loam, 30–40 inches.	.6	
B26732	R50A	do	*A. pectinatus*		2,660
B26733	R50B	do	Young wheat, 3–5 inches tall		40

DISCUSSION OF DATA BY COUNTIES

The part of Bottineau County in which indicator plants were observed is largely in the lacustrine area formerly covered by the waters of glacial Lake Souris. On large areas in the county neither *Astragalus pectinatus* nor *A. bisulcatus* was observed, and in these areas no soil samples were taken. Thirty-five samples of soil and vegetation were collected at 14 locations. The 15 samples of soil ranged in selenium content from 0.6 to 4 p. p. m., whereas the 11 samples of *A. bisulcatus* and 2 samples of *A. pectinatus* ranged from 270 to 4,400 p. p. m. The selenium content of the 7 samples of young wheat (B26888, B26893, B26914, B26917, B26925, B26928, and B26931) was 90, 8, 140, 60, 60, 60, and 70 p. p. m., respectively, and indicates the distinct possibility of toxic vegetation of ordinary food or forage type.

Samples were collected at 10 locations in Burke County. The soils varied in selenium content from 1 to 1.6 p. p. m. A soil (B26742) collected 20 miles north of Powers Lake contained 1.2 p. p. m. of

selenium, the *Astragalus pectinatus* (B26743) growing in it contained 1,870 p. p. m., and a sample of young wheat (B26744) growing within a few feet of it contained 30 p. p. m.

In Divide County the indicator plants were spotty in occurrence. All samples of soil were derived from glacial drift. Thirty-three samples of soil and vegetation were collected at 16 locations. The soils ranged in selenium content from 0.1 to 1.2 p. p. m., and the species of *Astragalus* from 160 p. p. m. in a sample thought to be *A. bisulcatus* (B26644) to a maximum of 4,740 p. p. m. in a sample (B26682) of *A. pectinatus*. Near a sample of soil (B26669) containing 0.6 p. p. m. of selenium, a sample of young wheat (B26671) was found to contain 20 p. p. m. and *A. pectinatus* (B26670) 1,780 p. p. m. It was the only *Astragalus* observed for a distance of more than 20 miles north of Alamo.

Fourteen samples were collected for selenium analysis in McHenry County, in the area north of a line running approximately from Minot southeast to Velva and then northeast to Rugby (*1*), formerly covered by a glacial lake. Four of the five locations were in this lacustrine area, and indicator plants were of common occurrence, whereas in the higher, roughly rolling area to the south, only one *Astragalus bisulcatus* (B26862) was observed. It contained 1,980 p. p. m. of selenium, and the soil (B26860) in which it grew 1.6 p. p. m. Young wheat (B26861) growing about 20 feet east of the *Astragalus* contained 35 p. p. m. and the soil beneath it (B26859) 1 p. p. m. In the lacustrine area 2 miles east of Deering, cattle were observed with symptoms of chronic selenium poisoning (fig. 1). A sample of soil (B26902) collected nearby

FIGURE 1.—Appearance of animal with a chronic case of mild selenium poisoning, McHenry County, N. Dak.

had a selenium content of 1.4 p. p. m. and a sample of mixed grasses (B26903) on which the animals were feeding contained 70 p. p. m. A sample of *A. bisulcatus* (B26904) collected in a ditch just outside the pasture contained 2,030 p. p. m.

The soils of McLean County are varied. The breaks to the Missouri River cut deeply into the county. The Fort Union formation is exposed along these breaks, but only at two locations were indicator plants observed growing in material of obvious Fort Union origin. Thirty-one samples of soil and vegetation were examined. The 15 soils ranged in selenium content from 0.4 to 2 p. p. m. A sample of *Astragalus caryocarpus* Ker (B26773) collected 3 miles east of Elbowoods in the Missouri River alluvium contained 120 p. p. m. of selenium, and the soil (B26772) in which it grew 0.8 p. p. m. Another sample of this species of *Astragalus* was found growing near an *A. bisulcatus* plant. The *A. bisulcatus* (B26857) contained 2,620 p. p. m. of selenium, whereas in the *A. caryocarpus* (B26858) the content was only 30 p. p. m.

Fifty-two samples of soil and vegetation were collected at 25 locations in Mountrail County. The 23 samples of soils ranged in selenium content from 0.4 to 8 p. p. m. The 22 samples of *Astragalus pectinatus* ranged from 190 to 3,720 p. p. m. Samples B26785 to B26790, inclusive, were collected on the farm of A. L. Edwards, 10 miles northwest of Plaza. A soil sample (B26783) taken from his pasture contained 0.8 p. p. m. of selenium. A number of plants of *A. pectinatus* (B26786) growing on and nearby the soil sample had a selenium content of 3,600 p. p. m. A sample of mixed grasses "grazed" from among these *Astragalus* plants contained 130 p. p. m. A sample of oats from the barn contained 7 p. p. m., of oat trash 30 p. p. m., and of barley 2 p. p. m. Chronic selenium poisoning in animals on the A. L. Edwards farm caused the sloughing off of deformed hoofs and the loss of the switch from the tail. In spite of abundant feed, pigs and cattle afflicted with selenium poisoning on that farm made poor progress (fig. 2.)

The Souris River (Mouse River on some maps) flows southeastward across Renville County. Much of the terrain of the county is rough, owing to the eroded breaks to this stream. Selenium indicator plants were observed only on the gently rolling plains away from the stream. On these plains 20 samples of soil and vegetation were collected at 9 locations. The 9 soil samples ranged in selenium content from 0.2 to 2 p. p. m., and 7 samples of *Astragalus bisulcatus* ranged from 110 to 1,520 p. p. m. Two locations are interesting because of the high selenium content of the young wheat found on them. On a sample of soil (B26874) containing 1.6 p. p. m. of selenium, a sample of *A. bisulcatus* (B26875) was found to contain 1,520 p. p. m., and a sample of young wheat (B26876) collected within 4 feet of the soil contained 130 p. p. m. A surface soil sample (B26879) taken 5 miles north of Mohall contained 2 p. p. m.; *A. bisulcatus* (B26880) growing in the soil 1,280 p. p. m.; and young wheat (B26881) growing 15 to 18 feet from the soil sample 80 p. p. m.

A sample of *Astragalus bisulcatus*, found in a road cut 4 miles east of Mercer, in Sheridan County, contained 620 p. p. m. of selenium, and the soil in which it grew, 0.8 p. p. m. No other indicator plants were observed in the county.

FIGURE 2.—"Runt" calf and others of about the same age, afflicted with selenium poisoning, on the farm of A. L. Edwards, Mountrail County, N. Dak.

Forty-eight samples of soil and vegetation were collected at 21 locations in Ward County. The 21 samples of soil ranged in selenium content from 0.2 to 3 p. p. m. Eleven samples of *Astragalus pectinatus* contained from 140 to 3,190 p. p. m., and 7 samples of *A. bisulcatus* ranged from 80 to 1,730 p. p. m. A sample of young winter rye (B26815) containing 15 p. p. m. of selenium was found growing on a soil (B26814) with a selenium content of 0.8 p. p. m. Also, at a point 3 miles south of Deslacs on a soil (B26825) containing 0.6 p. p. m., a sample of young winter rye (B26836) contained 30 p. p. m. No indicator plants were observed in the vicinity of these rye samples. The selenium in these soils appears to be readily available for plants. A soil sample (B26839) collected 4 miles north of Douglas contained 0.4 p. p. m. of selenium, *A. pectinatus* (B26840) growing in the soil 2,280 p. p. m., and a sample of *Astragalus* (B26841) too immature to identify the species, growing nearby, 90 p. p. m. Three miles north of this location cattle were observed that had lost the switch from their tails (fig. 3).

Fifty samples of soil and vegetation were collected in Williams County. The 24 samples of soil ranged in selenium content from 0.4 to 8 p. p. m. The 21 samples of *Astragalus pectinatus* contained from

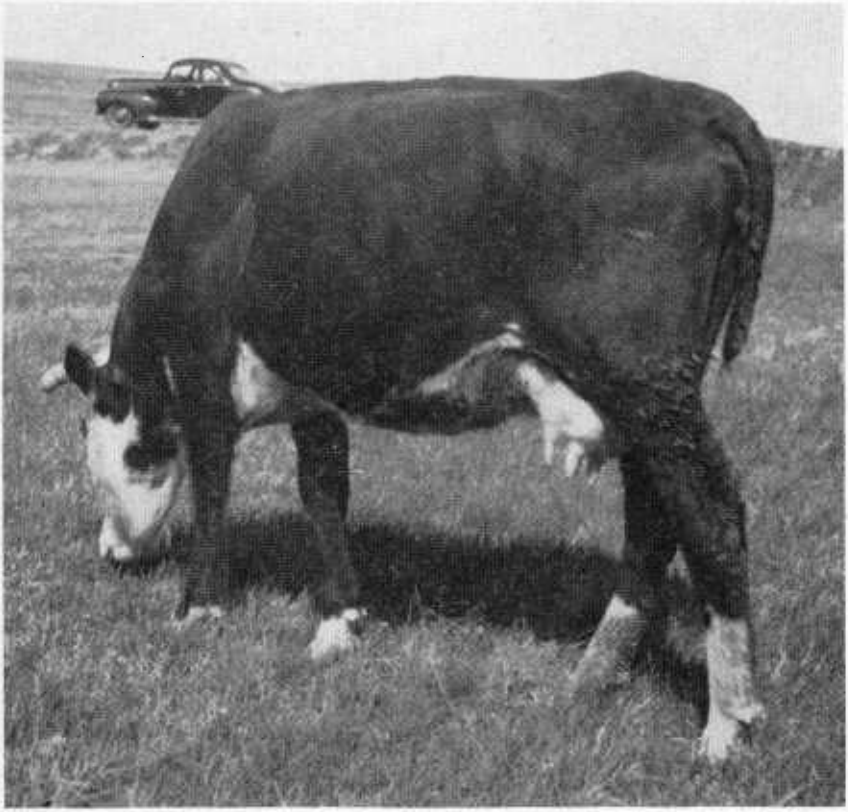

FIGURE 3.—Brushless tail on Hereford cow indicates mild selenium poisoning; Ward County, N. Dak.

520 to 3,990 p. p. m. A sample of soil (B26672) collected 5 miles north of Epping contained 1 p. p. m., the *A. pectinatus* growing in it 1,460 p. p. m., and a sample of young wheat (B26674) taken nearby 35 p. p. m. Another sample of young wheat (B26733) and a sample of young winter rye (B26691) contained 40 and 20 p. p. m., respectively. As in other counties previously discussed, no selenium-indicator plants were observed in much of this area. The seleniferous soils appear to be limited for the most part to gently rolling glacial areas, as illustrated in figure 4. The Fort Union formation, which underlies the glacial drift, is exposed in the southern part of the county (fig. 5). Although these exposures of Fort Union were crossed at several points, only one sample of soil definitely developed from Fort Union material in situ was found supporting a selenium-indicator plant. This soil (B26657) contained 1 p. p. m. of selenium, and the *A. pectinatus* growing in it contained 1,280 p. p. m.

Very high selenium content has been reported in the material near the junction of the Niobrara and Pierre formations of Cretaceous age in South Dakota, Nebraska, Kansas, and Wyoming (*6*, *7*, *10*, *20*). With the cooperation of Frank C. Foley, professor of geology, Univer-

sity of North Dakota, the writers were able to collect samples of material from the lower part of the Pierre formation and from the upper part of the Niobrara formation in Cavalier County. The results of the analysis of these samples are given in table 1. The eight samples of shale contained from 1.4 to 36 p. p. m. of selenium. A sample of

FIGURE 4.—Gently rolling area of seleniferous soils in Williams County, N. Dak.

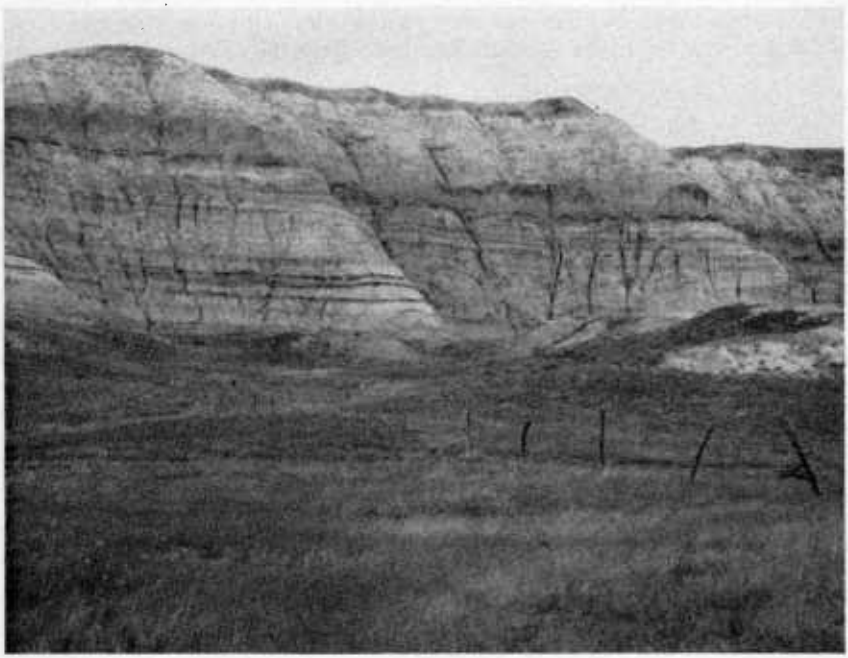

FIGURE 5.—Exposure of mildly seleniferous Fort Union formation near Hofflund, Williams County, N. Dak.

Astragalus (B26417) collected in the abandoned pit of the Mayo Brick & Tile Co. contained 1,660 p. p. m. of selenium. This plant was collected early in the spring and was therefore too immature to be identified as to species. The more interesting samples were those obtained at the former workings of the Northern Cement & Plaster

Co., 2 miles southwest of Concrete. These samples (B26420 to B26425, inclusive) were collected at the junction of the Pierre and Niobrara formations (*1*). The limonite layer (B26422) formed the junction between the two formations and contained 34 p. p. m. of selenium. The Pierre shale (B26421), immediately above the junction, contained 32 p. p. m., and the Niobrara nodule (B26423), just below the limonite layer, had a selenium content of 36 p. p. m. The "cement rock" of the Niobrara (B26424) contained 14 p. p. m. These analyses are of special interest because they greatly extend the known area in which the upper part of the Niobrara formation and the lower part of the Pierre formation contain large quantities of selenium. The lower part of the Pierre formation has been reported to contain from 10 to 20 p. p. m. in Logan County, Kans. (*7*), 8 to 31 p. p. m. in Harlan County, Nebr. (*6*), 45 p. p. m. in Yankton County, S. Dak. (*21*), and 21 p. p. m. in Niobrara County, Wyo. (*21*). The upper part of the Niobrara formation contains similar quantities (*6*, *7*, *21*).

When one considers that it is approximately 800 miles from Logan County, Kans., to Cavalier County, N. Dak., it is exceedingly difficult to conceive that a given horizon in a sedimentary formation could be so uniformly high in selenium content throughout so great an area. Yet it appears to be true, for everywhere that this junction has been examined the selenium content has been from 10 to 30 p. p. m.

General Discussion

Three hundred and twenty-four samples of soils, minerals, and vegetation were collected at 143 locations in North Dakota. The selenium content of the 154 samples of soil ranged from 0.1 to 8 p. p. m. The 91 samples of *Astragalus pectinatus* ranged from 140 to 4,950 p. p. m. Thirty-nine samples of *A. bisulcatus* contained from 70 to 4,400 p. p. m. The 26 samples of young barley, rye, and wheat plants ranged in selenium content from 8 to 140 p. p. m.

The selenium content of the vegetation is high, although the soils are not unusually seleniferous. At least one reason for this apparent disparity lies in the time of the year that the samples were collected. This survey was made during the latter half of May, when the *Astragalus* plants and small grains were only a few inches high.

It is to be expected that the early spring growth of vegetation would be higher than mature plants in selenium content. To illustrate, a sample of *Astragalus racemosus* collected in Lyman County, S. Dak., on May 27, 1938, contained 2,600 p. p. m. Samples from the same plant showed a selenium content of 790 p. p. m. on July 16 and 630 p. p. m. on August 29 of the same year (*34*). Also, a sample of young wheat grown in Wyoming contained 45 p. p. m., whereas the mature grain from the same plot contained only 2 p. p. m. (*6*). In like manner four samples of young wheat collected in the first week of June in Canada showed a selenium content of 30 to 140 p. p. m. (*9*), yet the commercial wheat of this area, as represented by 230 composites of 2,230 samples, is reported to have a selenium content of 1.5 p. p. m. or less (*26*). These data on wheat in Canada are

of the same order of magnitude in both young wheat and commercial grain as those obtained in North Dakota.

The relatively low selenium content of mature grain, in contrast to the highly seleniferous spring growth, no doubt accounts partly for the lack of widespread reports of alkali disease. Oral information indicates considerable injury to and loss of stock through troubles known locally as "frozen feet." One of the characteristics of chronic selenium poisoning is malformation and even loss of hoofs of livestock. These effects can well be mistakenly believed to be due to freezing. Ergot poisoning has been reported in the area. The reported symptoms of this type of poisoning are deformed hoofs and loss of the switch from the tail. In an early phase of the investigation selenium poisoning was confused with ergot poisoning (*12*). It would appear that this confusion persists locally among farmers.

It is interesting to note that *Astragalus pectinatus* was far less common in Bottineau and McHenry Counties than *A. bisulcatus*, whereas the reverse conditon was true in the counties farther west. A similar situation was observed in Canada and is reflected in the relative number of each species collected (*9*). In Alberta two samples of *A. pectinatus* were collected to one of *A. bisulcatus* and in Saskatchewan about an equal number of each species were taken. In Manitoba, however, only *A. bisulcatus* was obtained.

It should not be inferred that seleniferous soils derived from glacial drift are found only in the northwestern part of North Dakota. The glaciers moving southward over exposed Pierre shale in the eastern half of North Dakota gathered material and deposited it as drift. Some seleniferous soils can therefore be expected. A few examples are known. In Dickey County, 11 miles north of Ellendale, the surface soil (B26934) contained 0.8 p. p. m. of selenium, and young barley (B26936) growing in it contained 15 p. p. m. In a road cut nearby, a soil sample (B26935), taken at a depth of 4 to 5 feet, contained 0.6 p. p. m.; and *Astragalus bisulcatus* (B26937) growing in the cut contained 570 p. p. m. Alkali disease has been reported on a farm 20 miles west of Ellendale. Also, a sample of soil (B26932) collected in Balta, Pierce County, contained 0.5 p. p. m. of selenium; and *A. bisulcatus* (B26933) growing in this soil, 720 p. p. m. Thomas Leonard reported stock poisoning, with symptoms indicating selenium poisoning, on his farm in Rolette County. *A. bisulcatus* was observed along the shore of a lake 5 miles west of Medina in Stutsman County.

No effort has been made to discover to what extent the soils are seleniferous in North Dakota west of the Missouri River. Samples of minerals and soils from McKenzie County, however, have been found to contain selenium. A sample of pyrites (B26628), collected in an exposure of the Fort Union formation, contained 10 p. p. m. of selenium. A sample of heavy, dark clay, collected 1.4 miles west of Johnsons Corners, McKenzie County, contained 0.5 p. p. m. Yellow concretions taken nearby contained 2 p. p. m., and a sample of *Astragalus bisulcatus* contained 60 p. p. m. Alkali disease has been reported a few miles to the south of Johnsons Corners, and one of the writers observed *A. pectinatus* in the vicinity of Beach in Golden Valley County.

SELENIUM IN UTAH, NEVADA, IDAHO, AND OREGON

During the progress of these selenium investigations a number of samples were examined from various sections of Utah, Nevada, and Idaho. Seven samples of Cretaceous shales, collected in eastern Utah and reported by Byers (*6*), ranged in selenium content from 0.2 to 8 p. p. m. Areas of seleniferous soil in the vicinity of Tropic and Escalante, Utah, have been reported (*10*). Both of these areas are of extremely rough topography, and the extent of actually toxic soil is probably very small. An area of much larger extent, reported southwest and east of Price, Utah (*10*), consists of a broad band of soil derived wholly or in part from the Mancos formation of Cretaceous age, covers an irregular strip of territory probably aggregating 1,000 square miles, and extends eastward beyond the Colorado line. Miscellaneous samples of selenium-indicator plants have been received and analyzed by the Division from these areas in Utah (*33*) and from the western part of the State. Beath and associates (*4*) have made similar observations of widely scattered seleniferous soils in the State. Holt and Greaves (*14*) have reported relatively low selenium in the principal forage plants of Utah.

Examination of shallow-well waters and of surface soils for selenium from the United States Newlands Field Station, at Fallon, Nev., showed a range of selenium concentration in the subsurface water of 1 to 560 parts per billion, whereas the soils contained from a mere trace to 1 p. p. m. (*10*). These observations demonstrate that seleniferous spots may be found in the alluvial Pliocene deposits occurring over a large part of Nevada and particularly in the Carson and Humboldt Sinks. Another area of seleniferous soil in Clark County has been reported (*17*). In this area the soil appears to be derived from alluvial soils. Beath, Gilbert, and Eppson (*4*) have reported the occurrence of seleniferous-indicator plants in alluvial deposits in various locations in Nevada. Nothing of definite character is known concerning the extent of such areas, of the intensity of the toxicity of the vegetation, or of the extent of the resulting injury to animals.

In 1938, 15 samples of soil and vegetation, collected in the Snake River Valley, in southwestern Idaho, were analyzed for selenium. Six samples of *Stanleya* contained 0.5 to 330 p. p. m. of selenium and two of the soils contained selenium to the extent of 2.5 and 12 p. p. m. (*34*). Beath and associates (*4*) have also reported seleniferous-indicator plants from this area.

The many indications of isolated areas of seleniferous soils in Utah, Nevada, and Idaho made it seem advisable to investigate further the possibility of large areas of seleniferous soils in the Great Basin area.

Early in the spring of 1940 a reconnaissance trip was made through parts of Utah, Nevada, Idaho, and Oregon. Samples were collected on the basis both of geological considerations and of the occurrence of indicator plants. A number of *Astragalus* plants, not known to be selenium indicators, were collected for selenium analysis and when sufficiently mature were identified by the Division of Plant Exploration and Introduction, of this Bureau. The results of the examination of these samples, together with those obtained from other sources, are given in table 2.

TABLE 2.—*Selenium content of soils, minerals, and vegetation from Utah, Nevada, Idaho, and Oregon*

UTAH

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil or mineral	Vegetation
				P. p. m.	*P. p. m.*
B26437	8	21 miles east of Roosevelt, on U. S. No. 40.	Soft red sandy sedimentary rock.	0.2	
B26440	8A	do	*Astragalus flavus*		30
B26441	9	23 miles west of Roosevelt, on U. S. No. 40.	Yellowish-brown silt loam	.4	
B26442	9A	do	*Astragalus* sp		40
B26443	10	6 miles north of Provo, at mouth of Provo Canyon.	Dark-brown clay loam, 0–12 inches.	20	
B26444	10A	do	*Stanleya pinnata*		1,440
B26445	10X	do	Manning Canyon shale	54	
B26446	10Y	do	Gray limestone, embedded with shale.	12	
B26447	10B	do	Grape leaves and new growth stems.		40
B26448	10C	do	Indian paintbrush		4
B26449	11X	8 miles northeast of Provo, in Provo Canyon.	Manning Canyon shale	12	
B26450	11Y	do	Limestone in shale	8	
B26451	11A	do	*A. cibarius*		70
B26452	11B	do	*S. pinnata*		300
B26453	12X	7 miles northeast of Provo, in Provo Canyon.	Great Blue limestone	1.2	
B26466	21	3 miles north of Tooele	Gravelly brown loam, 0–8 inches.	.2	
B26467	21A	do	*A. utahensis*		25
B26468	22X	19 miles southwest of Tooele	Gold ore from Lark Incline mine.	26	
B26469	22Y	do	Manning Canyon shale	4	
B26471	24X	2 miles northwest of Manning Mill, in Manning Canyon.	do	.4	
B26472	24Y	do	Red band in shale, containing pyrite.	5	
B26473	25X	Snyder mines in Mercur	Concentration fines from base ore.	15	
B26474	26X	35 miles north-northwest of Delta, Juab County.	Red deposits from hot springs	(1)	
B26475	26Y	do	Lava	.2	
B26476	27X	35 miles west of Black Rock, at Crystal Mountain, Millard County.	White silicon deposit	.1	
B26477	27	do	Light-gray calcareous sandy loam.	.1	
B26478	27A	do	*Stanleya* sp		25
B26479	27Y	do	Fossiliferous limestone	.1	
B26480	28	2 miles east of Crystal Mountain, Millard County.	Light-gray calcareous sandy loam, 0–8 inches.	.2	
B26481	28X	do	Caliche in soil	.1	
B26482	28A	do	*Stanleya* sp		10
B26483	28B	do	Brigham tea		1
B26484	29	18 miles east of Crystal Mountain, Millard County.	Yellowish-gray calcareous silt loam, 0–10 inches.	.4	
B26485	29A	do	*Stanleya* sp		60
B26486	30	17 miles east of Black Rock, Millard County.	Light-brown silt loam, 0–12 inches.	.1	
B26487	30A	do	*A. araneosus*		5
B26488	31A	19 miles east of Black Rock, Millard County.	*A. araneosus* (?)		4
B26489	32A	12 miles east of Cove Fort, Sevier County.	do		2
B26490	33	18 miles east of Cove Fort, Sevier County.	Brown sandy loam, 0–12 inches	.1	
B26491	33A	do	*A. utahensis*		15
B26492	33B	do	*Actinea richardsoni*		2
B26493	34	21 miles west of Salt Lake City, U. S. No. 40.	Brown silt loam, 0–10 inches	.4	
B26494	34A	do	*Astragalus beckwithii*		.2
B26495	35	95 miles west of Salt Lake City, U. S. No. 40.	Desert mud	.6	
B26977	1	1 mile north of Colton, on U. S. No. 50, Utah County.	*Astragalus* sp		7
B26978	2	1 mile north of Castlegate, on U. S. No. 50, Carbon County.	*Stanleya* sp		670

See footnote at end of table.

TABLE 2.—*Selenium content of soils, minerals, and vegetation from Utah, Nevada, Idaho, and Oregon*—Continued

UTAH—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil or mineral	Vegetation
				P. p. m.	*P. p. m.*
B26979	3	1 mile south of Helper, on U. S. No. 50, Carbon County.	*Stanleya* sp		150
B26980	3A	do	*Astragalus* sp		1
B26981	4	3 miles south of Price, on State Route 10.	*Stanleya* sp		470
B26982	5	2 miles south of Huntington, on State Route 10, Emery County.	do		160
B26983	5A	do	Unidentified plant		2
B26984	6	15 miles north of Loa, on State Route 72, Sevier County.	*Astragalus* sp		2
B26985	7	2 miles below Fish Lake road junction, on State Route 24, Piute County.	do		.5
B26986	8	3.1 miles southeast of junction of U. S. No. 89 and State Road 24, Sevier County.	*Stanleya* sp		4
B26987	9	3 miles west of Fillmore, Millard County.	Grass from volcanic crater		.5
B27241	40-3	3 miles south of Price	*A. flavus*, unidentified		4
B27242	do	do	*A. flavus*, fruiting stems		.2
B27242A	do	do	*A. flavus*, entire plant		1
B27243	40-4	do	*A. coltoni*		(1)
B27244	40-5	1 mile south of Price	*A. musiniensis*		1
B27263	40-33	5 miles east of Utah-Nevada State line, on Route 27.	*S. pinnata*		1
B27264	40-54	do	*Astragalus* sp		10
B27265	40-55	do	do		(1)

NEVADA

B26496	36	2 miles west of Wendover, Utah, on U. S. No. 40.	Gravelly gray silt loam, 0–10 inches.	0.1	
B26497	36A	do	*A. araneosus*		1
B26498	37	4 miles west of Wendover, Utah, on U. S. No. 40.	Grayish-brown silt loam, 12–30 inches.	.2	
B26499	37A	do	*A. beckwithii*		.2
B26500	38	5 miles west of Wendover, Utah, on U. S. No. 40.	Gravelly grayish-brown silt loam, 0–10 inches.	.4	
B26501	38A	do	*Stanleya* sp		3
B26502	39	25 miles west of Wendover, Utah, on U. S. No. 40.	Chalky light-brown silt loam, 0–10 inches.	.2	
B26503	39A	do	*Stanleya* sp		3
B26504	40	22 miles north of Wells, on U. S. No. 93.	Brown silt loam, 0–8 inches	4	
B26505	40A	do	*A. iodanthus*		1
B27255	40-45	25.6 miles southeast of Eureka	*Nicotiana attenuata*		10
B27256	40-46	do	*A. toanus*		210
B27257	40-47	do	*A. scobinatulus*		320
B27258	40-48	do	*S. pinnata*		5
B27259	40-49	30.7 miles southeast of Eureka	do		140
B27260	40-50	do	*A. scobinalutus*		25
B27261	40-51	8 miles west of Hamilton	*S. pinnata*		.2
B27262	40-52	10 miles northwest of Hamilton	*S. pinnata*		2
B26968		6 miles east of Wellington	Gray calcareous fine sandy loam, 0–6 inches.	.3	
B26969		do	Parent rock	.2	
B26970		do	*S. pinnata*		5
B26971		do	*Astragalus* sp		1
B26972		do	*Salvia carnosa*		.5
B26282	1	3 miles north of Pahrump ranch, Clark County.	Gravelly silt, 0–8 inches	.1	
B27268	1	do	*Stanleya* sp		2
B27272	2	½ mile north of Manse ranch, Clark County.	Sandy soil, 4–10 inches	.1	
B27269	2	do	*Stanleya* sp		3
B27273	3	Midway between Manse and Younts ranches, Clark County.	Gravelly sandy silt, 2–8 inches	.1	
B27267	3	do	*Stanleya* sp		6

See footnote at end of table.

TABLE 2.—*Selenium content of soils, minerals, and vegetation from Utah, Nevada, Idaho, and Oregon*—Continued

NEVADA—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil or mineral	Vegetation
				P. p. m.	*P. p. m.*
B27274	4	2 miles east of Younts ranch, Clark County.	Gravelly sandy silt, 2–8 inches	0.1	
B27270	4	do	*Stanleya* sp		6
B27281	5	3 miles east of Younts ranch, Clark County.	Light-colored calcareous silt, 0–10 inches.	.2	
B27271	5	do	*Stanleya* sp		3
B27275	6	10 miles east of Younts ranch, Clark County.	Light-colored calcareous silt, 0–6 inches.	.1	
B27278	6	do	*Astragalus* sp		1
B27276	7	6 miles southeast of Manse ranch, Clark County.	Gravelly silt, 1–6 inches	.1	
B27279	7	do	*Astragalus* sp		(1)
B27277	8	5 miles southeast of Manse ranch, Clark County.	Gravelly sandy loam, 1–8 inches	.1	
B27280	8	do	*Astragalus* sp		(1)
B27287	AC–1	Coyote Springs Valley near north end of Arrow Canyon Range, Clark County.	White silt	.1	
B27283	AC–1	do	*Stanleya* sp		10
B27286	MM–1	Muddy Peak Basin, Muddy Mountains.	Gravelly calcareous silt, 0–7 inches.	.1	
B27284	MM–1	do	*Stanleya* sp		3
B27285	MM–1	do	*Astragalus* sp		.4

IDAHO

B26506	41	6 miles southeast of Hagerman, on U. S. No. 30.	Light-brown silt loam, 0–12 inches.	0.05	
B26507	41A	do	*A. molocus*		1
B26508	42	4 miles north of Hagerman, on U. S. No. 30.	Gray calcareous silt loam, 0–10 inches.	.05	
B26509	42A	do	*A. lyallii*		1
B26510	43	7 miles east of New Plymouth	Calcareous light-brown silt loam, 3–4 feet.	.05	
B26511	43A	do	*A. beckwithii*		1
B26512	44	5½ miles east of New Plymouth	Light-brown calcareous silt loam, 0–8 inches.	.4	
B26513	44A	do	*A. beckwithii*		4
B26551	65	1 mile west of Givens Springs	Light-gray compact silt loam	.8	
B26552	65A	do	*Stanleya* sp		230
B26553	66	4 miles east of Givens Springs	Gray silt loam	.2	
B26554	66A	do	*Stanleya* sp		50
B26555	66B	do	*Atriplex confertifolia*		10
B26556	67	7 miles southeast of Walters	Brown sandy loam, 0–10 inches	.05	
B26557	67A	do	*Astragalus speirocarpus*		10
B26558	68	9 miles northwest of Grand View, on road to Oreana.	Gray silt loam, 0–10 inches	.05	
B26559	68A	do	*Stanleya* sp		7
B26560	69	10 miles southeast of Grand View, on road to Bruneau.	Gray silt loam, 0–10 inches	.05	
B26561	69A	do	*Stanleya* sp		2
B26562	69B	do	*A. speirocarpus*		7
B26563	69C	do	Indian paintbrush		1
B26564	70	8½ miles south of Bruneau	Dark-gray silt loam, 0–10 inches	6.0	
B26565	70X	do	Hard compact silt loam, 15–20 inches.	.4	
B26566	70A	do	*A. loanus*		990
B26567	70B	do	*Stanleya* sp		150
B26568	70C	do	*A. speirocarpus*		6
B26569	70D	Purdue farm, ½ mile east of State Road 70.	Irrigated corn, 1939 crop		1
B26570	71X	12 miles south of Bruneau	White silicious earth	(1)	
B26571	72	1.2 miles north of Bruneau, on road to Mountain Home.	Gray sandy loam, 0–10 inches	.05	
B26572	72A	do	*Stanleya* sp		390

See footnote at end of table.

TABLE 2.—*Selenium content of soils, minerals, and vegetation from Utah, Nevada, Idaho, and Oregon*—Continued

IDAHO—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil or mineral	Vegetation
				P. p. m.	*P. p. m.*
B26573	73	7.2 miles southwest of Mountain Home.	Dark-brown silt loam, 0–8 inches.	0.4	
B26574	73	do	Gray-brown silt loam, 8–12 inches (hardpan).	.1	
B26575	73A	do	*Stanleya* sp		60
B26576	73B	do	Wild mustard		1
B26577	74	3.8 miles northwest of Mountain Home, on U. S. No. 30.	Gray silt loam, 0–8 inches	.3	
B26578	74A	do	*Astragalus* sp		6
B26579	75	3 miles west of Hammett, on U. S. No. 30.	Gray clay, 0–10 inches	.2	
B26580	75A	do	*A. toanus*		620
B26581	75B	do	*Bromus tectorum*, near B26580		8
B26582	75C	do	*B. tectorum*, 75 feet from B26580.		.2
B26583	75D	do	Wild parsnip leaves and seeds		2
B26584	75E	do	*Stanleya* sp		780
B26585	75F	do	Indian paintbrush		4
B26586	76	3 miles west of Hammett, 200 yards north of State Road 75 in cut.	Fine soft clay	.1	
B26587	76X	do	Hard white clay	.6	
B26588	76Y	do	Yellow soft coarse sandstone	(1)	
B26589	77	6 miles east of Hammett, on U. S. No. 30.	Gray silt loam, 0–10 inches	3	
B26590	77X	do	Lava	.6	
B26591	77A	do	*Stanleya* sp		1,290
B26592	78	0.6 mile east of Bliss, on U. S. No. 30.	Gray silt loam, 0–10 inches (under B26596).	1.6	
B26593	78Y	do	Gray shalelike clay, 24–30 inches.	.05	
B26594	78X	do	Lava from cap, about 200 feet above No. 78.	.05	
B26595	78Z	do	Yellowish-gray silt loam, 0–10 inches (under B26597).	.2	
B26596	78A	do	*A. toanus*		100
B26597	78B	do	*A. lyallii*		.5
B26598	78C	do	*A. malacus*		1
B26599	78D	do	*A. stenophyllus*		4
B26600	78E	do	*Stanleya bipinnata*		70
B26601	79	12 miles northwest of Buhl	Gray fine sandy loam, 0–10 inches.	.2	
B26602	79A	do	*Stanleya* sp		120
B26614	84X	8.7 miles east of Wayan, on Tincup Creek.	Gray shale	.1	
B26616	84	do	Gray clay loam, 0–8 inches, under B26618.	.6	
B26617	84Z	do	Limestone, under B26616	.1	
B26618	84A	do	*Corydalis aurea*		7
B26619	85X	13 miles east of Wayan, on Tincup Creek.	Thin-bedded reddish-brown shale.	.4	

OREGON

B26514	45	Oregon State Expt. Sta., at Vale.	Grayish-brown silt loam, 0–8 inches.	0.1	
B26515	46	1 mile east of Vale, on State Road 28.	Light brown silt loam, 0–10 inches.	.1	
B26516	46A	do	*A. nudisiliquus*		0.5
B26517	47	22 miles south of Ontario, on State Road 201.	Rotten ferruginous sandstone	.8	
B26518	47A	do	*A. nudisiliquus*		1
B26519	48A	In Sucker Creek Canyon, approaching Rockville.	*Astragalus* sp		1
B26520	49A	1½ miles southeast of Jordan Valley.	do		.5
B26521	50	30 miles west of Jordan Valley	Light-brown loam, 0–10 inches	.2	
B26522	50A	do	*Astragalus* sp		.5

See footnote at end of table.

TABLE 2.—*Selenium content of soils, minerals, and vegetation from Utah, Nevada, Idaho, and Oregon*—Continued

OREGON—Continued

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil or mineral	Vegetation
				P. p. m.	*P. p. m.*
B26523	51X	In cut along Owyhee River at Rome.	Yellowish-brown silt loam	0.2	
B26524	52	4 miles west of Rome, Malheur County.	Light-gray silt loam, in creek cut.	2.0	
B26525	52A	do	*Stanleya* sp		360
B26526	53	6 miles west of Rome, Malheur County.	Yellowish-brown calcareous gravelly loam, 0–10 inches.	.8	
B26527	53A	do	*Stanleya* sp		220
B26528	54	½ mile north of No. 53, Malheur County.	Gravelly grayish-brown loam, 0–10 inches.	2.0	
B26529	54A	do	*Stanleya* sp		60
B26530	55	6½ miles west of Rome, Malheur County.	Gray sandy loam, 0–10 inches	.8	
B26531	55X	do	Sandstone	.05	
B26532	55A	do	*Stanleya* sp		650
B26533	56	4 miles north of Rome, on road to Follyfarm.	Yellowish-brown sandy loam, 0–10 inches.	.8	
B26534	56A	do	*Stanleya* sp		180
B26535	57	6 miles northwest of Rome, on road to Follyfarm.	Light gravelly sandy loam, 0–10 inches.	.8	
B26536	57A	do	*Stanleya* sp		10
B26537	57B	do	*A. beckwithii*		1
B26538	58	8 miles northwest of Rome, on road to Follyfarm.	Light-gray sandy loam, 0–10 inches.	.2	
B26539	58A	do	*Stanleya* sp		7
B26540	58B	do	Indian paintbrush		4
B26541	59	5 miles south of State Road 54, on road to Riverside.	Light-brown silt loam, 0–10 inches.	.2	
B26542	59A	do	*Astragalus* sp		1
B26543	60	5 miles east of crossroad to Riverside, on State Road 54.	Diatomaceous earth	.1	
B26544	61	5 miles east of Juntura, on State Road 54.	Gray sandy loam	.05	
B26545	61A	do	*A. stenophyllus*		2
B26546	62	7 miles east of Juntura, on State Road 54.	Gravelly gray silt loam, 0–10 inches.	.05	
B26547	62A	do	*A. stenophyllus*		1
B26548	63	20 miles west of Vale, on State Road 54.	Diatomaceous earth	.2	
B26549	64	10 miles west of Vale, on State Road 54.	Brown silt loam, 0–10 inches	.1	
B26550	64A	do	Alfalfa		1

[1] None detected.

DISCUSSION OF DATA FOR UTAH

Sixty-three samples of soils, minerals, and vegetation were collected in Utah, samples B26977 to B26987, inclusive, by James A. Robertson, of Brigham Young University, and samples B27241 to B27244 and B27263 to B27265 by W. T. Huffmann, of the Bureau of Animal Industry, United States Department of Agriculture.

Of special interest are the data obtained in Provo Canyon, near the town of Provo. Beath and coauthors (*3*) reported rocks of Paleozoic age in Provo Canyon to be very seleniferous. James A. Robertson assisted the writers in locating the area involved. A sample of shale (B26445) taken at the mouth of Provo Canyon contained 54 p. p. m. of selenium, the soil (B26443) 20 p. p. m., and *Stanleya pinnata* (B26444) growing in the soil 1,440 p. p. m. Grape leaves and new-growth stems (B26447) collected in a vineyard nearby contained 40 p. p. m.

Ten samples of shale and interbedded limestone were collected at seven locations in exposures on both the east and the west side of Utah Lake. The selenium content of these shales and limestones ranged from 0.4 p. p. m. in a sample collected in Manning (B26471) to 54 p. p. m. in a sample taken 6 miles north of Provo (B26445). The formation from which these samples were collected is the Manning Canyon shale reported to be of Carboniferous age (*13*). It is evident that this formation varies considerably in selenium content and that it may give rise to highly seleniferous soils. No area of any considerable extent, however, is known in which the soils are derived from Manning Canyon shale. It is of interest primarily because it is the oldest sedimentary formation known to be seleniferous.

Twenty-eight samples of soils, minerals, and vegetation were collected at 13 locations in the western plains of Utah, in the region formerly covered by the ancient Bonneville Lake. The soil samples ranged in selenium content from 0.1 to 0.6 p. p. m. (table 2). Four samples of *Stanleya* (B27263, B26478, B26482, and B26485) contained 1, 25, 10, and 60 p. p. m., respectively. *Astragalus utahensis* Torr. and Gray (B26491) containing 15 p. p. m. was found 18 miles east of Cove Fort on a soil with a selenium content of only 0.1 p. p. m. Another sample of *A. utahensis* (B26467) collected 3 miles north of Tooele contained 25 p. p. m., whereas the soil on which it grew contained only 0.2 p. p. m. These samples do not indicate a highly seleniferous area. The *Astragali* and *Stanleya*, however, produce an early spring growth. Domestic animals, particularly sheep, are not careful in the selection of their food when they are being moved, and many large bands of sheep are driven across western Utah in spring. A knowledge of the existence of any considerable colonies of the selenium-indicator plants would be useful in avoiding losses of sheep caused by acute selenium poisoning, as it is the practice of sheepmen to circle areas containing poisonous range plants.

A number of samples of vegetation and a few soil samples collected in the drainage basin of the Green River in eastern Utah were analyzed for selenium and the results are included in table 2. These range from a sample of *Astragalus coltoni* Jones (B27243) with no detectable quantity of selenium to a *Stanleya* sample (B26978) containing 670 p. p. m. The area from which these samples were collected is reported by Byers and others (*10*) and Beath and others (*4*) to contain seleniferous soils.

Discussion of Data for Nevada

No formal and systematic investigation has been made of the occurrence of seleniferous soils in Nevada. However, a considerable mass of data has accumulated in the literature as a result of reconnaissance trips through the State by persons interested in the selenium problem. Reports by members of this division (*10*, *17*, *18*) and by Beath and others (*4*) have included fragmentary data on Nevada soils. Table 2 gives the data on Nevada accumulated since the last report.

Forty-four samples of soil, rock, and vegetation from Nevada are listed in table 2. Samples B27255 to B27262, inclusive, were furnished by H. W. Schoening, of the Bureau of Animal Industry;

samples B26968 to B26972, inclusive, by Ray C. Roberts, of the Division of Soil Survey, Bureau of Plant Industry, Soils, and Agricultural Engineering; and 21 samples of soil and vegetation collected in Clark County and vicinity were obtained through the assistance of C. R. Longwell, of Yale University.

An area of seleniferous soils has been reported in Clark County, Nev. (*17*, *18*). The area investigated consists roughly of part of the Las Vegas Valley, extending from 60 miles northwest to about 5 miles south of Las Vegas. It was not known how far eastward or westward this seleniferous area extended. The 21 samples were obtained to answer this question. Sixteen samples numbered 1 to 8, inclusive, were collected in valleys to the west of the Spring Mountains and also west of the Las Vegas Valley. The 2 samples numbered AC–1 and the 3 numbered MM–1 were collected in valleys northeast and east of Las Vegas. The soils were found to be uniformly low in selenium content, and the vegetation was correspondingly low. Seven samples of *Stanleya* ranged in selenium content from 2 to 10 p. p. m. It would appear that the seleniferous soils in Clark County are restricted to a relatively small area.

From the data presented here, together with those available in the literature, it may be said that there are numerous examples of mildly seleniferous soils scattered throughout most of the semidesert area of Nevada. Many, if not most, of these soils are developed from alluvial or lacustrine material. Whether the selenium observed in such material is due to seepage of water-soluble selenium from the adjacent mountains or to the erosion and deposition of seleniferous formations is unknown.

Discussion of Data for Idaho

Sixty-five samples of soil, rocks, and vegetation were collected at 22 locations in southwestern Idaho and examined for selenium (table 2). The 22 soil samples ranged in selenium content from none to 6 p. p. m. The 11 samples of *Stanleya* ranged from 2 p. p. m. (B26561) to 1,290 p. p. m. (B26591). Three samples of *Astragalus toanus* Jones contained from 100 to 990 p. p. m. These samples were taken in an area along the Snake River extending from Givens Springs near the Oregon State line, to Buhl, near the center of the State. The seleniferous soils in this area are of spotty occurrence. They appear to be derived from the lacustrine beds of the Payette formation of Miocene age. The lava (B26594) that overlies the Payette formation 0.6 mile east of Bliss (fig. 6) was found to contain only 0.05 p. p. m. of selenium, whereas the soil (B26592) collected under an *A. toanus* plant and presumably derived from the lacustrine material of the Payette formation contained 1.6 p. p. m. The *A. toanus* (B26596) contained 100 p. p. m. of selenium. A sample of lava (B26590) taken 6 miles east of Hammett had a selenium content of 0.6 p. p. m., the soil (B26589) at the same location 3 p. p. m., and a sample of *Stanleya* (B26591) 1,290 p. p. m. No selenium-indicator plants were observed on soils obviously derived from the lava flow of this area.

The United States Geologic Map [5] shows the existence of an ex-

[5] U. S. Geological Survey. Geologic map of the United States, 1932. Prepared by G. W. Stose and O. A. Lungstedt. 1933.

FIGURE 6.—Lava ledge (nonseleniferous) above Miocene bed (seleniferous), east of Bliss, Idaho.

posure of Cretaceous shales in an area along Tincup Creek in the northeastern part of Caribou County, Idaho. Six samples were collected in this region. Two samples of shale (B26614 and B26619) contained 0.1 and 0.4 p. p. m. of selenium, respectively, and a sample of limestone 0.1 p. p. m. A soil sample had a selenium content of 0.6 p. p. m., whereas a sample of *Corydalis aurea* Willd. (B26618) growing in this soil contained 7 p. p. m. It appears from these data that the Cretaceous shales exposed in this area are not seleniferous.

DISCUSSION OF DATA FOR OREGON

The United States Geologic Map [6] shows an area of Miocene deposits in Malheur County in eastern Oregon as a continuation of the Miocene deposits along the Snake River in western Idaho. In order to determine whether the seleniferous soils developed from similar deposits in Idaho also exist in eastern Oregon, 37 samples of soil, rocks, and vegetation were collected in the area. The results of selenium analysis of these samples are given in table 2. A seleniferous area was located in the vicinity of Rome, about 60 miles west of Jordan Valley in Malheur County. Eighteen samples (B26523–B26540) were collected at 8 locations in this area. The 8 soil samples ranged in selenium content from 0.2 p. p. m. (B26538) to 2 p. p. m. (B26528), whereas the 7 samples of *Stanleya* ranged from 7 p. p. m. (B26539) to 650 p. p. m. (B26532). A sample of Indian paintbrush (B26540) contained 4 p. p. m., and 1 of *Astragalus beckwithii* Torr. and Gray 1 p. p. m.

The seleniferous soils of this area, like those of Idaho, appear to be derived wholly from the lacustrine Payette deposits of Miocene age. These soils were found on the slopes below a sandstone ledge in the

[6] See footnote 5.

Owyhee Valley. To illustrate, the soil (B26530) collected on the slope below the sandstone ledge (fig. 7) contained 0.8 p. p. m. of selenium, and *Stanleya* (B26532) growing in this soil 650 p. p. m. A sample of sandstone from the ledge contained only 0.05 p. p. m. This sandstone was prominently exposed in the area, and no *Stanleya* plants were observed growing on or above it. No attempt was made

FIGURE 7.—Seleniferous soils (foreground) on slope below Miocene sandstone ledge, or "rim rock," 6½ miles west of Rome, Oreg.

to explore the whole of the area where Miocene deposits were indicated, but no other seleniferous soils were observed in the reconnaissance. No seleniferous soils have been previously reported in Oregon.

SELENIUM IN PYRITIC MINE SLIMES AT PARK CITY, UTAH

In the course of investigations by the Division of Soil Chemistry and Physics [7] on the seleniferous soils, pyrites have frequently been

[7] See footnote 4, p. 2.

found associated with the parent material of the soil. Selenium was found to occur in these nodules of iron pyrites in higher concentrations than in the mass of the material. This fact, coupled with the known occurrence of selenium in chamber sulfuric acid made by roasting pyrites, and the historic fact that selenium was discovered in 1817 in the sulfuric-acid chambers in which the sulfur dioxide used was derived from certain copper pyrites, made it of interest to determine how general the association of sulfur and selenium in pyrites may be.

In the course of the writers' surveys of areas in which seleniferous soils occur, a number of samples of pyrites and sulfide ores were examined (*6*, *7*, *30*). Seventy-eight of these samples of pyrites and sulfide ores contained an average of 95 p. p. m. of selenium, with a minimum of less than 1 p. p. m. and a maximum of 900 p. p. m. in an ore sample from Marysvale, Utah. This maximum value is due perhaps to tiemannite, a selenide of mercury, as this mineral is found in Marysvale. Twenty-three of the sulfides reported in this group contained more than 100 p. p. m. of selenium, while 80 percent of the samples contained 10 p. p. m. or more.

In the working of sulfide ore mines, slime dumps rich in sulfides accumulate. These mine dumps are frequently in natural stream beds, and the mining companies make considerable effort to prevent their being carried away. Settling basins in the stream below the dumps are used in many cases. Sufficient slime frequently passes these settling basins, however, to give a milky appearance to the water, and occasional floods will carry large quantities of the sulfide slimes and deposit them in the flood plains below the mining operations.

Two examples of selenium-bearing slimes from mining operations on flood plains are known. One of these, described by Byers (*8*), was found in the valley of the Guanajuato River, State of Guanajuato, Mexico, where chronic poisoning of domestic animals and possibly of human beings had resulted. The occurrence of the seleniferous area in Mexico brought about by deposition of seleniferous mine waste on alluvial soils of the stream flowing by the mine dumps suggested the possibility of similar situations in the United States. No area of the same magnitude or as dangerous to the public health has been found. A small area in the vicinity of Park City, Utah, however, resembles the Mexican situation in many respects.

Ore was discovered in Park City, 27 miles east of Salt Lake City, in 1869, and mines were opened the following year. Silver, gold, lead, zinc, and a little copper are taken from sulfide ores: 73,500 ounces of gold and about 1,100,000 ounces of silver were shipped from the two mines operating there in 1939; 20,000 tons of lead and zinc also were obtained (*35*, *p. 378*). This ore is ground and concentrated, and the metal-rich fraction is sent to a smelter at Salt Lake City.

The slimes discarded in the flotation are dumped along the edge of Silver Creek. Because of complaints by farmers along Silver Creek and the Weber River, into which the slimes eventually are carried by Silver Creek, a settling basin was established by the mining companies. In times of high water or of increased activity at the mines, the flow from the settling basin is milky with slimes.

Some years ago a sample of lead concentrate from these mines was obtained by T. D. Rice, of the Division of Soil Survey, of this Bureau,

and analyzed for selenium by the writers. It contained 385 p. p. m. of selenium (*6*). This analysis, coupled with the complaints of the farmers along the streams affected, led to a preliminary investigation of the area to see whether selenium was a factor in the losses of cattle and horses. These losses were reputed to be due to lead poisoning caused by the slimes deposited on the forage that the animals ingested.

The method of sampling was similar in plan to that used in Irapuato, Mexico (*8*). The ores, slimes, and silted water, and the soils and vegetation of the flood plain, as well as the soils above the flood plain, were examined for selenium. The data obtained in this examination are given in table 3.

TABLE 3.—*Selenium content of soils, minerals, pyritic slimes, and vegetation in the vicinity of Park City, Utah*

Laboratory No.	Field No.	Place of collection	Material	Selenium in—	
				Soil or mineral	Vegetation
				P. p. m.	*P. p. m.*
B26454	13X	Park City, Utah	Sulfide ore	540	
B26455	14X	do	Carbonate ore	60	
B26460	16	1½ miles east of Park City	Water from Silver Creek, above settling basin.	.001	
B26460	16	do	Sediment from water No. 16	25	
B26461	17X	2½ miles east of Park City, at settling basin.	Mine slimes in basin	75	
B26456	15X	½ mile north of settling basin	Mine slimes in Silver Creek	70	
B26457	15Y	do	Sulfide-rich mud in Silver Creek.	125	
B26458	15A	do	Mixed grasses		5
B26459	15B	do	Reddish-brown algae in Silver Creek.		15
B27216	PC1	½ mile north of settling basin, east side above flood plain.	Gray silt loam, 0–8 inches	.4	
B27217	PC1A	do	*Juncus balticus*		1
B27218	PC2	½ mile north of settling basin, east side of flood plain.	Gravelly fine sand, pyritic, 0–8 inches.	60	
B27219	PC2A	do	*J. balticus*		1
B27220	PC3	½ mile north of settling basin, 15 feet north of PC2.	Gravelly fine sand, pyritic	60	
B27221	PC3A	do	*Carex* sp		1
B27222	PC3B	½ mile north of settling basin, between PC2 and PC3.	Willow leaflets		1
B27223	PC4	½ mile north of settling basin, west side of flood plain.	Sandy loam, pyritic, 6–12 inches.	30	
B27224	PC4A	do	Sedge peat, 0–6 inches		70
B27225	PC5	½ mile north of settling basin, west side above flood plain.	Brown gravelly loam, 0–6 inches.	.4	
B27226	PC5A	do	*Aster* sp		1
B27227	PC6	4 miles north of settling basin, along Silver Creek.	Fine sand, 0–7 inches, in flood plain.	45	
B27228	PC6A	do	Sedge peat, 7–24 inches		25
B27229	PC6B	do	Sedge growing in PC6		2
B27230	PC7	4 miles north of settling basin, along Silver Creek, east side, above flood plain.	Brown loam, 0–8 inches, irrigated from Silver Creek.	3	
B27231	PC7A	do	Alfalfa growing in PC7		.5
B27232	PC8	5½ miles north of settling basin, along Silver Creek.	Brown loam, 0–8 inches, irrigated.	.4	
B27233	PC8A	do	Alfalfa		(1)
B27234	PC9	5½ miles north of settling basin, along Silver Creek, 150 yards west of PC8, in flood plain.	Mottled yellowish-gray silt loam, 0–8 inches.	20	
B27235	PC9A	do	Mixture, *Juncus* and *Carex*		1
B26462	18X	6 miles southwest of Wanship, up Silver Creek.	Mud from Silver Creek	40	
B26463	19X	In eddy of Silver Creek, at Wanship.	do	20	
B26464	20X	1 mile south of Wanship, in eddy of Weber River.	Mud from Weber River, above Silver Creek.	.1	
B26465	21X	1 mile north of Wanship, in eddy of Weber River.	Mud from Weber River, below Silver Creek.	5	

[1] None detected.

A sample of sulfide ore (B26454) contained 540 p. p. m. of selenium. This sample consisted primarily of sulfides and no doubt would run higher than the average ore rock from the mines. A sample of carbonate ore (B26455) contained 60 p. p. m.

The silty water in Silver Creek above the settling basin was collected and the silt removed by settling and filtration. The clear water (B26460) thus obtained contained only 1 part per billion, or 0.001 part per million of selenium, whereas the silt contained 25 p. p. m. Water taken in a similar location at Irapuato, Mexico, contained 200 times as much selenium, while the content of the silt from the Irapuato water was only one-third as high. A sample of sulfide-rich slime (B26461) collected in the Utah settling basin contained 75 p. p. m.

Below the settling basin, Silver Creek is broken into numerous streamlets that meander down a flat alluvial valley about one-half to three-fourths of a mile wide near the dam at the settling basin. These streamlets converge to a single stream as the creek enters Silver Creek Canyon some 7 miles north of the settling basin.

One-half mile below the settling basin a series of samples were collected at intervals across the valley. Each of the soils (B27216 and B27225) obtained above the flood plain on the east and west sides of the valley contained only 0.4 p. p. m. of selenium. Six samples of alluvial soil collected in the floor of the valley contained from 30 to 125 p. p. m., with an average of 70 p. p. m.

Four miles north of the basin a sample of the alluvial material (B27227) contained 45 p. p. m. of selenium. In the fenced area in the valley from which this sample was taken, a number of horses had been poisoned, and local veterinarians gave the cause of death as lead poisoning from the slime dust on the feed. One cow in this field developed elongated hoofs characteristic of selenium poisoning. The bench above the field is irrigated by water carried in ditches from Silver Creek. This water is occasionally milky with mine slimes. The irrigated soil (B27230) contained 3 p. p. m. of selenium.

Five and one-half miles north of the settling basin the selenium content of the alluvial material (B27234) at the edge of the flood area was 20 p. p. m. The irrigated benchland (B27232) contained only 0.4 p. p. m.

At the beginning of the canyon, 7 miles north of the settling basin (6 miles southwest of Wanship), a sample of alluvial material (B26462) contained 40 p. p. m. of selenium; at Wanship, similar material (B26463) contained 20 p. p. m.

One mile west of Wanship, Silver Creek flows into the Weber River, which carries three to five times as much water as the creek, so it was expected that very little effect would be observable in the selenium content of the silt load of the Weber after Silver Creek had emptied into it. A sample of sediment (B26464) in an eddy of the Weber 1 mile southeast of the mouth of Silver Creek, however, showed a selenium content of 0.1 p. p. m., whereas a similar sample (B26465), taken a mile below the mouth of Silver Creek, contained 5 p. p. m. It is evident from the data presented that selenium in the slimes of the mine is being transported down Silver Creek and into the Weber River.

The selenium content of these slimes, which ranges from 5 p. p. m. in the Weber to 75 p. p. m. at the settling basin, would be sufficient to produce very toxic vegetation if the selenium were in a form available to the plants (*31*). The vegetative cover of the alluvial flat through which Silver Creek meanders and deposits most of its slime load consists of small rushes (*Juncus balticus* Willd.), sedge (*Carex* sp.), and willows (*Salix* spp.). A mixed sample (B26458) of *J. balticus* and *Carex*, collected one-half mile north of the settling basin early in the spring, contained 5 p. p. m., and a sample of reddish-brown algae (B26459) from the stream contained 15 p. p. m. When one of the writers visited the area again in August, however, only one sample of growing vegetation (B27229) contained as much as 2 p. p. m. Two samples of sedge peat (B27224 and B27228) contained 70 and 25 p. p. m., respectively, but these samples were contaminated with slimes. It is evident that the selenium in the alluvium along Silver Creek is not in a form that is particularly available to plants; consequently, no seriously toxic plants are to be found growing there.

The Mexican (*8*) and the Park City mining operations are similar, in that both work sulfide ores primarily for silver, the ores in both contain selenium, and the slimes from both contaminate the alluvial plains below the mines with material relatively rich in selenium. They differ markedly, however, in the quantities of selenium contained in the ores, slimes, and alluvial material. The maximum selenium content of the ores examined at Irapuato, Mexico, was 60 p. p. m., whereas at Park City a sample of sulfide ore (B26454) contained 540 p. p. m., nine times as much as that found at Irapuato. The maximum selenium content of the slimes and mine wastes at Irapuato was 30 p. p. m., whereas the Park City area contained as high as 125 p. p. m. and averaged 70 p. p. m.

The alluvial plain at Park City is characterized by a relatively high selenium content and is restricted to essentially nonagricultural land, whereas at Irapuato the slimes are distributed by flood and irrigation over a large area of agricultural land, which contains about one-fifth as much selenium as the Park City alluvium. Although the selenium content of the ores, slimes, and alluvial deposits is consistently higher in the Park City area, the quantity of selenium absorbed by plants is markedly lower—so low that the vegetation cannot be considered toxic.

This difference in availability of the selenium in the two mining areas is also made apparent in water analyses. The water below the mines at Irapuato contains 200 times as much water-soluble selenium as that at Silver Creek.

A difference in the kind of sulfide ores would account for the differences in rate of weathering. Marcasite, a mineral that weathers very rapidly, was observed at Irapuato but not at Park City.

It should also be noted that the Mexican mine has been in operation for at least 200 years, whereas the Park City mines have been worked for only a little more than 70 years. Perhaps in 130 years the Park City slimes will be spread over the irrigated bottom land of the Weber River, and will involve agricultural land in the same way as the slimes from the Mexican mines.

GENERAL DISCUSSION

Previous reports have been concerned largely with work done on the seleniferous character of soils derived from definite marine formations, primarily of Cretaceous age. Although some of the work herein reported is of a similar character, the major part of this report is concerned with seleniferous soils derived from glacial, lacustrine, and recent alluvial materials.

Whatever the process or combination of processes that result in selenium accumulation in geological formations of wide extent, such as the Pierre and Niobrara sediments, it is evident that somewhat smaller areas are produced by the mechanical transportation and leaching by ice or water of previously formed seleniferous deposits. Much of the data in this bulletin has to do with this type of seleniferous area.

In parts of North Dakota, Montana, and Canada, the glaciers deposited a mantle of debris, much of it relatively local in origin. It naturally follows that if the geologic formation thus disturbed is seleniferous, the soils developed from the debris will be seleniferous. Where seleniferous drift has been deposited in the vicinity of a glacial lake, such as the ancient Lake Souris, selenium may be leached from the surrounding drift and enrich the seleniferous material mechanically transported into the lacustrine beds. Thus, one might expect soils formed from these lacustrine deposits to be higher than the surrounding region in available selenium. That this process has occurred in the lacustrine beds of the glacial Lake Souris is indicated by the data from McHenry, Renville, and Bottineau Counties, N. Dak., as well as by the observation of Thorvaldson and Johnson (*26*) that wheat grown on soil of glacial lacustrine origin predominated among the samples of Canadian wheat having the higher selenium content.

During the time when much of the Great Basin was occupied by a lake or lakes of great extent, the products of erosion of the mountains to the east and west were deposited in these lake basins. After the present Colorado and Snake Rivers cut through the encircling barriers and eventually drained these lakes, the lacustrine material so exposed became the parent material of many of the soils of western Utah, Nevada, and parts of Idaho and Oregon. If any of the materials deposited in these lacustrine beds were eroded from seleniferous sources, the beds containing this material would be seleniferous. Likewise, any water-soluble selenium that was carried into these lakes by streams would be trapped in these lacustrine beds rather than carried to the sea (*10*). As these lakes gradually receded, subsequent leaching of selenium may have resulted in local concentrations in areas not otherwise exceptionally seleniferous. This combination of processes could result in the distribution of seleniferous soils that has been observed in the Great Basin. Thus, in the lacustrine beds of the Payette formation in Idaho and Oregon, seleniferous material, perhaps from older Cretaceous beds to the east, made up much of the stream loads deposited in the lake. In western Utah and Nevada, however, no great mass of the lacustrine beds appears to be particularly seleniferous. The occasional occurrence of small areas of selenium concentration in the soils of this area can best be explained by local concentration through leaching of material at higher levels.

LITERATURE CITED

(1) BARRY, J. G., and MELSTED, V. J.
1908. THE GEOLOGY OF NORTHEASTERN NORTH DAKOTA WITH SPECIAL REFERENCE TO CEMENT MATERIALS. *In* Leonard, A. G., State Geological Survey of North Dakota. Fifth Bien. Rpt., pp. 115–211, illus.

(2) BEATH, O. A., DRAIZE, J. H., EPPSON, H. F., and others.
1934. CERTAIN POISONOUS PLANTS OF WYOMING ACTIVATED BY SELENIUM AND THEIR ASSOCIATION WITH RESPECT TO SOIL TYPES. Amer. Pharm. Assoc. Jour. 23: 94–97.

(3) ——— GILBERT, C. S., and EPPSON, H. F.
1939. THE USE OF INDICATOR PLANTS IN LOCATING SELENIFEROUS AREAS IN WESTERN UNITED STATES. I. GENERAL. Amer. Jour. Bot. 26: 257–269, illus.

(4) ——— GILBERT, C. S., and EPPSON, H. F.
1939. THE USE OF INDICATOR PLANTS IN LOCATING SELENIFEROUS AREAS IN WESTERN UNITED STATES. II. CORRELATION STUDIES BY STATES. Amer. Jour. Bot. 26: 296–315, illus.

(5) ——— GILBERT, C. S., and EPPSON, H. F.
1940. THE USE OF INDICATOR PLANTS IN LOCATING SELENIFEROUS AREAS IN WESTERN UNITED STATES. III. FURTHER STUDIES. Amer. Jour. Bot. 27: 564–573, illus.

(6) BYERS, H. G.
1935. SELENIUM OCCURRENCE IN CERTAIN SOILS OF THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS. U. S. Dept. Agr. Tech. Bul. 482, 48 pp., illus.

(7) ———
1936. SELENIUM OCCURRENCE IN CERTAIN SOILS OF THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS. SECOND REPORT. U. S. Dept. Agr. Tech. Bul. 530, 79 pp., illus.

(8) ———
1937. SELENIUM IN MEXICO. Indus. and Engin. Chem. 29: 1200–1202, illus.

(9) ——— and LAKIN, H. W.
1939. SELENIUM IN CANADA. Canad. Jour. Res., Sec. B., Chem. Sci. 17: 364–369.

(10) ——— MILLER, J. T., WILLIAMS, K. T., and LAKIN, H. W.
1938. SELENIUM OCCURRENCE IN CERTAIN SOILS IN THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS: THIRD REPORT. U. S. Dept. Agr. Tech. Bul. 601, 75 pp., illus.

(11) FRANKE, K. W., and POTTER, V. R.
1935. A NEW TOXICANT OCCURRING NATURALLY IN CERTAIN SAMPLES OF PLANT FOODSTUFFS. IX. TOXIC EFFECTS OF ORALLY INGESTED SELENIUM. Jour. Nutr. 10: 213–221.

(12) ——— RICE, T. D., JOHNSON, A. G., and SCHOENING, H. W.
1934. REPORT ON A PRELIMINARY FIELD SURVEY OF THE SO-CALLED "ALKALI DISEASE" OF LIVESTOCK. U. S. Dept. Agr. Cir. 320, 10 pp., illus.

(13) GILLULY, J.
1932. GEOLOGY AND ORE DEPOSITS OF THE STOCKTON AND FAIRFIELD QUADRANGLES, UTAH. U. S. Geol. Survey Prof. Paper 173, 171 pp., illus.

(14) HOLT, W. L., and GREAVES, J. E.
1941. THE OCCURRENCE OF SELENIUM IN UTAH FORAGE PLANTS. Soil Sci. 51: 299–306.

(15) HURD-KARRER, A. M.
1935. FACTORS AFFECTING THE ABSORPTION OF SELENIUM FROM SOILS BY PLANTS. Jour. Agr. Res. 50: 413–427, illus.

(16) LAKIN, H. W., and BYERS, H. G.
1941. SELENIUM IN WHEAT AND WHEAT PRODUCTS. Cereal Chem. 18: 73–78.

(17) ——— and BYERS, H. G.
1941. SELENIUM OCCURRENCE IN CERTAIN SOILS OF THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS: SIXTH REPORT. U. S. Dept. Agr. Tech. Bul. 783, 26 pp.

(18) LAKIN, H. W., and HERMANN, F. J.
1940. ASTRAGALUS ARTEMISIARUM JONES AS A SELENIUM ABSORBER. Amer. Jour. Bot. 27: 245–246.
(19) MILLER, J. T., and BYERS, H. G.
1937. SELENIUM IN PLANTS IN RELATION TO ITS OCCURRENCE IN SOILS. Jour. Agr. Res. 55: 59–68, illus.
(20) MOXON, A. L.
1937. ALKALI DISEASE OR SELENIUM POISONING. S. Dak. Agr. Expt. Sta. Bul. 311, 91 pp., illus.
(21) ——— OLSON, O. E., and SEARIGHT, W. V.
1939. SELENIUM IN ROCKS, SOILS AND PLANTS. S. Dak. Agr. Expt. Sta. Tech. Bul. 2, 94 pp., illus.
(22) MUNSELL, H. E., DEVANEY, G. M., and KENNEDY, M. H.
1936. TOXICITY OF FOOD CONTAINING SELENIUM AS SHOWN BY ITS EFFECT ON THE RAT. U. S. Dept. Agr. Tech. Bul. 534, 25 pp., illus.
(23) ROBINSON, W. O.
1933. DETERMINATION OF SELENIUM IN WHEAT AND SOILS. Assoc. Off. Agr. Chem. Jour. 16: 423–424.
(24) ——— DUDLEY, H. C., WILLIAMS, K. T., and BYERS, H. G.
1934. DETERMINATION OF SELENIUM AND ARSENIC BY DISTILLATION IN PYRITES, SHALES, SOILS, AND AGRICULTURAL PRODUCTS. Indus. and Engin. Chem., Analyt. Ed. 6: 274–276, illus.
(25) SMITH, M. I., FRANKE, K. W., and WESTFALL, B. B.
1936. THE SELENIUM PROBLEM IN RELATION TO PUBLIC HEALTH. A PRELIMINARY SURVEY TO DETERMINE THE POSSIBILITY OF SELENIUM INTOXICATION IN THE RURAL POPULATION ON SELENIFEROUS SOIL. U. S. Pub. Health Serv. Rpts. 51: 1496–1505.
(26) THORVALDSON, T., and JOHNSON, L. R.
1940. THE SELENIUM CONTENT OF SASKATCHEWAN WHEAT. Canad. Jour. Res., Sect. B., Chem. Sci. 18: 138–150, illus.
(27) TRELEASE, S. F., and TRELEASE, H. M.
1938. SELENIUM AS A STIMULATING AND POSSIBLY ESSENTIAL ELEMENT FOR INDICATOR PLANTS. Amer. Jour. Bot. 25: 372–380, illus.
(28) ——— and TRELEASE, H. M.
1938. SELENIUM AS A STIMULATING AND POSSIBLY ESSENTIAL ELEMENT FOR CERTAIN PLANTS. Sci. 87: 70–71.
(29) ——— and TRELEASE, H. M.
1939. PHYSIOLOGICAL DIFFERENTIATION IN ASTRAGALUS WITH REFERENCE TO SELENIUM. Amer. Jour. Bot. 26: 530–535, illus.
(30) WILLIAMS, K. T., and BYERS, H. G.
1934. OCCURRENCE OF SELENIUM IN PYRITES. Indus. and Engin. Chem., Analyt. Ed. 6: 296–297.
(31) ——— and BYERS, H. G.
1936. SELENIUM COMPOUNDS IN SOILS. Indus. and Engin. Chem. 28: 912–914.
(32) ——— and LAKIN, H. W.
1935. DETERMINATION OF SELENIUM IN ORGANIC MATTER. Indus. and Engin. Chem., Analyt. Ed. 7: 409–410.
(33) ——— LAKIN, H. W., and BYERS, H. G.
1940. SELENIUM OCCURRENCE IN CERTAIN SOILS IN THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS: FOURTH REPORT. U. S. Dept. Agr. Tech. Bul. 702, 60 pp., illus.
(34) ——— LAKIN, H. W., and BYERS, H. G.
1941. SELENIUM OCCURRENCE IN CERTAIN SOILS IN THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS: FIFTH REPORT. U. S. Dept. Agr. Tech. Bul. 758, 70 pp., illus.
(35) WRITERS PROGRAM OF THE U. S. WORK PROJECTS ADMINISTRATION.
1941. UTAH: A GUIDE TO THE STATE. American Guide series. 595 pp., illus. New York.

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