Annotated Bibliography on the Geology of Selenium

GEOLOGICAL SURVEY BULLETIN 1019-M

U.S. DEPARTMENT OF THE INTERIOR
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G. W. Luttrell—ANNOTATED BIBLIOGRAPHY ON THE GEOLOGY OF SELENIUM—Geological Survey Bulletin 1019-M

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By GWENDOLYN W. LUTTRELL

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ANNOTATED BIBLIOGRAPHY ON THE GEOLOGY OF SELENIUM

By Gwendolyn W. Luttrell

ABSTRACT

This bibliography includes annotations of nearly 400 papers on the geologic occurrence, mineralogy, and geochemistry of selenium, as well as papers on metallurgy, analytical procedures, biologic effects, production, and uses of selenium which are of geologic interest. A summary of the uses, mineralogy, geochemistry, and geologic occurrence of selenium is contained in the introduction.

INTRODUCTION

Selenium, a comparatively rare element, is playing an increasingly large part in manufacturing processes and in articles of everyday use because of its unique properties. Selenium was discovered by J. J. Berzelius in 1817, but it remained only a laboratory curiosity until one of its valuable properties, its variation in electrical resistance when exposed to light, was discovered by Willoughby Smith in 1873. Since then, this and other unusual properties of selenium, especially its rectifying property, or the ability to change alternating to direct current, have led to its wide use in industry.

The two principal uses for selenium, accounting for 50 percent and 25 percent respectively of U. S. consumption, are in rectifiers and pigments. Rectifiers are used in voltage multiplier circuits, in other electronic devices, and in television and radio equipment. Selenium pigments impart a red color to paint, ceramics, rubber, paper, silks, leather, and other products. Other uses for selenium are as a decolorizer in flint glass; as a coloring agent in ruby and amber industrial glass; as a degasser in the manufacture of stainless steel, where it also improves machinability; as an alloying element to increase the machinability of copper; as a vulcanizing agent in rubber, where it improves resistance to heat, oxidation, and abrasion; as a catalyst in the preparation of drugs and pharmaceuticals; as an antioxidant in lubricating oils; in photoelectric cells; as a toner in photography; in blasting caps; in insecticides; as a resin solvent; and in the separation and purification of hydrocarbons. Many of these uses are increasing, and the resulting demand has stimulated research on the geology and geochemistry of selenium, for it is through such studies that new sources of the element will be found.

The ores of many of the world's large copper mines contain minute amounts of selenium, and at present the most important commercial source of selenium is copper anode slimes from which it is recovered as a byproduct. Increased demand for selenium has led to improved practices in byproduct recovery, so that the supply has increased notably in recent years. Selenium also is produced as a byproduct of the flash roasting of pyrites in the manufacture of sulfuric acid.

United States production of selenium in 1954 was 713,200 pounds and imports in that year were 209,600 pounds, as reported in the Bureau of Mines Minerals Yearbook for 1954. The price of selenium, which was $1.50 per pound in the early 1930's, increased to a high of $18.50 for 99.99 percent selenium in late 1956, but dropped to $13.50 in mid-1957.

GEOCHEMISTRY

The distribution of selenium in nature and its concentration in ore deposits are subjects which have not been given detailed study until recently. The abundance of selenium in magmatic rocks given by V. M. Goldschmidt (1954) is 0.09 ppm. The atomic number of selenium is 34 and its atomic weight is 78.96; selenium is between sulfur and tellurium in the periodic table, and it is closely related to these elements in certain aspects of its geochemical behavior. Selenium is a chalcophile element and has a high affinity for sulfur. The atomic radii of selenium and sulfur are so similar that selenium readily replaces sulfur diadochically in sulfide minerals. The substitution appears to occur more readily at high than at low temperatures, for the sulfur-selenium ratio ranges from 400:1 to 20,000:1 in high temperature sulfides, but ranges from 70,000:1 to 250,000:1 in low temperature magmatic sulfides. Selenium also accompanies sulfur in some volcanic sulfur deposits.

The close relationship between sulfur and selenium in primary ores does not continue during the cycle of weathering and leaching because a much higher oxidation potential is required to oxidize selenides to selenates than to oxidize sulfides to sulfates, and the low oxidation potential under which weathering commonly takes place is not sufficient to form selenates. Ordinarily only selenites form, and these are readily removed from solution by reduction or absorption. Thus selenium is separated from sulfur in evaporites and in sulfur deposits formed by the reduction of sulfates. Very little of the selenium carried into sea water remains in solution, the bulk of it being removed with organic matter, iron and manganese hydroxides, and iron sulfide.

MINERALOGY

Selenium occurs in nature in crystalline and amorphous elemental form; in solid solution with tellurium and sulfur; combined with other metals as selenides, sulfoselenides, selenites, and selenates; in many sulfide and sulfosalt minerals in which it substitutes for a small part of the sulfur in the crystal lattice; and as an oxide of selenium.

A list of minerals of selenium follows. Selenium is listed in the formulas of minerals in which it may be a major constituent.

Minerals of selenium

Selenides, sulfoselenides	*Composition*
Achavalite	$FeSe$(?)
Aguilarite	Ag_4SeS
Berzelianite	Cu_2Se
Bornhardtite	$(Co, Cu, Ni)_3Se_4$(?)
Cadmoselite	$Cd (Se, S)$
Clausthalite	$PbSe$
Crookesite	$(Cu, Tl, Ag)_2Se$
Eskebornite	$CuFe_3Se_4$(?)
Eucairite	$CuAgSe$
Ferroselite	$FeSe_2$
Guanajuatite (frenzelite, castillite)	Bi_2Se_3
Hastite	$(Co, Fe)Se_3$
Klockmannite	$CuSe$
Metacinnabar, selenian (onofrite, guadalcazarite)	$Hg(S, Se)$
Naumannite (cacheutaite)	Ag_2Se
Paraguanajuatite	Bi_2Se_3
Penroseite (blockite)	$(Ni, Cu, Pb)Se_2$
Stilleite	$ZnSe$
Tiemannite	$HgSe$
Trogtalite	$CoSe_2$
Umangite	Cu_3Se_2
Unnamed cobalt selenide	$CoSe$(?)
Sulfides and tellurides	
Argentite	Ag_2S
Arsenopyrite	$FeAsS$
Bismuthinite	$Bi_2(S,Se)_3$
Bornite	Cu_5FeS_4
Chalcopyrite	$CuFeS_2$
Cinnabar	HgS
Csiklovaite	Bi_2TeS_2
Galena	PbS
Gruenlingite	Bi_4TeS_3
Joseite	Bi_3TeS(?)
Marcasite	FeS_2
Molybdenite	MoS_2

Minerals of selenium—Continued

Sulfides and tellurides—Continued	*Composition*
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$
Siegenite (selenosiegenite)	$(Co,Ni)_3(S,Se)_4$
Sphalerite (wurtzite)	ZnS
Stannite	Cu_2FeSnS_4
Stibnite	Sb_2S_3
Tetradymite	Bi_2Te_2S
Troilite	FeS
Vaesite (selenovaesite)	$Ni(S,Se)_2$
Villamaninite (bravoite)	$(Ni,Fe,Cu)S_2$
Sulfosalts	
Chiviatite	$Pb_3Bi_8(S,Se)_{15}$(?)
Cosalite (selenocosalite)	$Pb_2Bi_2(S,Se)_5$
Kobellite (selenokobellite)	$Pb_2(Bi,Sb)_2(S,Se)_5$(?)
Platynite	$PbBi_2(Se,S)_3$(?)
Tetrahedrite	$(Cu,Fe)_{12}Sb_4S_{13}$
Weibullite (seleniferous galenobismutite)	$PbBi_2(S,Se)_4$(?)
Wittite	$Pb_5Bi_6(S,Se)_{14}$(?)
Selenites	
Ahlfeldite	$NiSeO_3 \cdot 6H_2O$(?)
Chalcomenite	$CuSeO_3 \cdot 2H_2O$
Cobaltomenite	hydrous cobalt selenite
Selenite or selenate	
Kerstenite (molybdomenite)	hydrous lead selenite or selenate $PbSeO_4$(?)
Tellurite	
Emmonsite (durdenite)	$Fe_2(TeO_3)_3 \cdot 2H_2O?SeO_2$
Oxide	
Selenolite	SeO_2
Mixtures of selenides	
Lehrbachite	Tiemannite, clausthalite
Zorgite, "seebachite"	Clausthalite, umangite, tiemannite
Tilkerodite, selenkobaltblei	Clausthalite, cobaltite, hematite

GEOLOGIC OCCURRENCE

Selenium occurs in metallic ore deposits, most commonly in hydrothermal base metal sulfide deposits of all temperature and depth ranges. It is present in disseminated copper deposits of the porphyry type, in vein and replacement copper deposits, in massive sulfide ores, in copper-lead sulfide vein deposits, in epithermal silver-gold veins, in quicksilver and antimony deposits, and in the sandstone-type uranium-vanadium deposits of the Western United States. It is also present in volcanic emanations and deposits. Selenium also occurs as a trace element in many sedimentary deposits, particularly coals, volcanic tuffs, phosphate deposits, and sedimentary iron ores. It is present in shales and other sedimentary rocks, and in soils and vegetation associated with or derived from seleniferous formations.

In hydrothermal base metal sulfide deposits most of the selenium replaces sulfur in the lattices of sulfide minerals, such as pyrite, chalcopyrite, sphalerite, galena, marcasite, and arsenopyrite. Selenium minerals have been identified only in a few massive sulfide deposits, and sulfide vein deposits.

Selenium has been detected in amounts of not more than a few hundredths of a percent in the ores of most of the world's large copper deposits, including the disseminated deposits at Ray and Morenci, Ariz.; Ely, Nev.; Bingham, Utah; Chino, N. Mex.; and Cananea, Mexico; and the replacement and vein deposits of Butte, Montana; Cerro de Pasco, Peru; Northern Rhodesia; and Belgian Congo. Some of the better known seleniferous massive sulfide deposits are at Rio Tinto, Spain; Mt. Lyell, Tasmania; Mt. Isa, Queensland; Bor, Yugoslavia; Boliden, Sweden; Flin Flon, Manitoba; Sudbury, Ontario; and Ducktown, Tenn.

In certain sulfide vein deposits a variety of selenium minerals is found. The copper-silver-lead veins of Skrikerum, Sweden; Harz Mountains, Germany; Copiapo, Chile; and Colquechaca, Bolivia; and the pitchblende-bearing sulfide veins of Goldfields, Saskatchewan, and Shinkolobwe, Belgian Congo are characterized by a wide variety and abundance of selenium minerals.

Selenium minerals are found in many epithermal silver-gold fissure vein deposits. Examples are deposits in the Silver City district, Idaho; Comstock Lode and Jarbidge district, Nev.; and Guanajuato, Mexico, where naumannite, sometimes in large quantities, has been identified. Unidentified selenium minerals in combination with gold and silver are found in the Republic district, Wash., and in Radjang Lebong, Sumatra. The seleniferous silver-gold ores of Tonopah and Aurora, Nev.; San Francisco district, Utah; and the Liberty Bell mine, Telluride district, Colo., all contain small amounts of an unidentified black mineral, which is possibly a gold or silver selenide.

Some epithermal quicksilver deposits contain tiemannite. Tiemannite has been noted at Buckskin Peak, Nev.; the Abbott mine, Calif.; the Lucky Boy mine, Piute County, Utah; and at Guadalcazar, San Onofre, and Huitzuco, Guerrero, Mexico. At Huitzuco the selenium is associated with antimony ores.

In most epithermal veins selenium minerals are rare, but in a few deposits they constitute a major part of the ore. At the Lucky Boy quicksilver mine the ore consisted almost entirely of tiemannite, and at the De Lamar mine, Silver City district, Idaho, the principal silver mineral was naumannite, although it was mistaken for argentite. The unusual deposit at Radjang Lebong, Sumatra, consists of a combination of gold and silver with selenium.

A few rare veins of selenide minerals are known in which sulfide minerals are absent. The Hiaco (Pacajake) silver mine near Colquechaca, Bolivia, and the silver-lead selenide vein at Cerro de Cacheuta, Argentina, are veins that contain only selenide minerals and a few secondary selenite minerals.

Uranium deposits in sandstone in the Western United States generally contain selenium in association with sulfide minerals or with carbonaceous material. Recent studies have shown that the selenium in some of these deposits occurs in elemental crystalline form, but in most the element seems to be substituting for sulfur in sulfide minerals.

Selenium is found associated with products of volcanic origin. A volcanic tuff deposit in Fremont County, Wyo., was found to be seleniferous, and soils derived from volcanic materials in the Hawaiian Islands are seleniferous. The source of the selenium in the Hawaiian soils is believed to be volcanic gases and sublimates. Seleniferous sulfur of volcanic origin has been reported from the Valley of Ten Thousand Smokes, Alaska; from Krisuvik, Iceland; from Vesuvius, Lipari Island, and Sicily, Italy; from Kilauea, T. H.; from Tateyama and Iwojima Islands, Japan; and from New Zealand. Seleniferous sulfur locally containing as much as 5.18 percent selenium is reported from Kilauea, T. H.

Selenium is a minor constituent of rocks and soils in many areas. The average concentration of selenium in shale calculated by Krauskopf (1955) is 0.5–1 ppm; in sandstone 1 ppm; in limestone 0.1–1 ppm. These figures are tentative, based on only a few published analyses. An unusually large concentration of selenium in the rocks and soils of certain of the Western United States has attracted much attention because of livestock losses resulting from selenium poisoning and the possibility that humans may suffer ill effects from consumption of seleniferous grains and crops.

The selenium in sedimentary shales and sandstones may have been derived from volcanic dust or gases, or from decomposed igneous rocks in which it was a primary constituent, and deposited by normal processes in the seas. Sedimentary iron oxide formations and pyrite concretions in sedimentary rocks are enriched in selenium. The selenium in these rocks is believed to represent the removal by ferric ions of selenium carried into sea water.

Selenium in soils commonly is derived from the parent rocks, although surface ground water containing selenium may increase the content.

In the Western United States the most seleniferous formations are shales and sandstones for the most part of Cretaceous age, but certain Permian, Triassic, Jurassic, and Tertiary formations are also highly seleniferous. These are found in Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, Idaho, and Wyoming. Certain plants, including species of *Astragalus*, *Stanleya*, and *Xylorrhiza*, which require selenium for growth, are found in these areas. These plants, called indicator plants, absorb large amounts of selenium from the soil and convert it into a form available to other vegetation. Indicator plants frequently contain enough selenium to be toxic to grazing animals.

Soils with an unusually high content of selenium are also found in Ireland, Japan, Mexico, Cuba, Colombia, Puerto Rico, and Hawaii. The seleniferous soils of Hawaii and Puerto Rico are unusual in that although they contain a high concentration of selenium they do not support seleniferous vegetation. It is thought that in regions such as these selenium is combined with iron in an insoluble form.

Phosphate rock deposits, particularly those that contain pyrite and large amounts of organic material, are among the most seleniferous sedimentary rocks known. Recent studies have shown that phosphate rock from the Phosphoria formation in Wyoming contains up to 300 ppm selenium, and a vanadiferous shale in the Phosphoria formation locally contains as much as 1500 ppm selenium. Dark colored phosphate rock from the Western United States and Canada, most Tennessee "blue rock," South Carolina phosphates, and phosphates from Africa and Palestine contain unusually large amounts of selenium.

Selenium has been found in coal in England and Belgium, where it is believed to be associated with pyrite seams.

EXPLANATION OF ANNOTATED BIBLIOGRAPHY

This bibliography includes annotated references to papers on the geologic occurrence, mineralogy, and geochemistry of selenium; and papers on other subjects such as metallurgy, analytical procedures, biologic effects, production, and uses of selenium, which also contain geologic information. Annotations taken from "Chemical Abstracts" give the page or column number and volume. The maps (pl. 5 and fig. 2) show the location of ore deposits in which selenium minerals have been found or in which selenium occurs as an ore constituent. Areas of seleniferous soils and rocks and seleniferous sulfur, coal, and phosphate deposits are not shown on the maps.

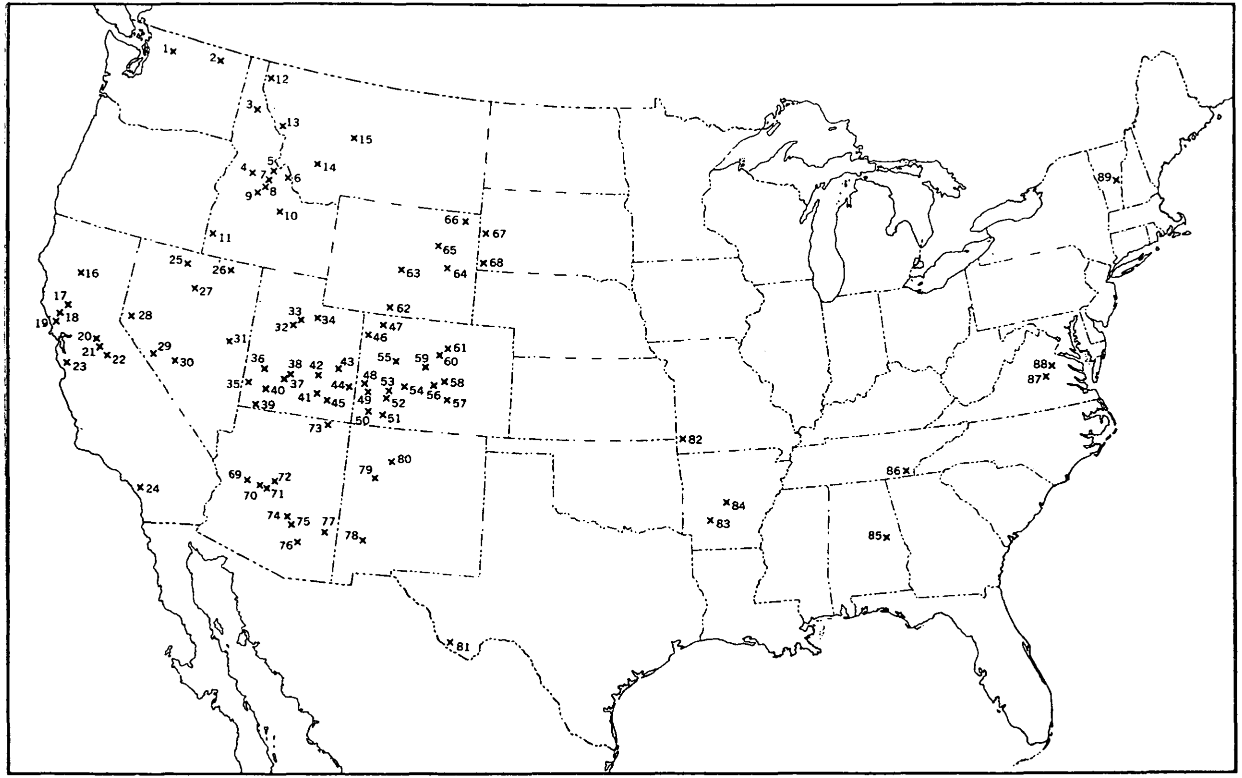

FIGURE 2.—Map showing selenium bearing ore deposits of the United States.

EXPLANATION OF FIGURE 2

Locality	Mine or district	County	State
1	Chelan Lake district	Chelan	Washington.*
2	Republic district	Ferry	Do.
3	Coeur d'Alene district	Shoshone	Idaho.
4	Yellow Pine district	Valley	Do.*
5	Blackbird district	Lemhi	Do.
6	Kirtley Creek district	do	Do.
7	Gravel Range district	do	Do.
8	Parker Mountain district	do	Do.
9	Yankee Fork district	Custer	Do.
10	Mackay district	do	Do.*
11	Silver City district	Owyhee	Do.
12	Troy district	Lincoln	Montana.*
13	Cedar Creek district	Mineral	Do.*
14	Butte district	Silver Bow	Do.
15	Montana district	Cascade	Do.*
16	Iron Mountain district	Shasta	California.
17	Abbott and Clear Lake	Lake	Do.
18	Socrates mine	Sonoma	Do.
19	Mt. Jackson mine	do	Do.*
20	Mother Lode	Amador	Do.*
21	Murphys district Mother Lode	Calaveras	Do.
22	Mother Lode	Tuolumne	Do.
23	Guadalupe mine	Santa Clara	Do.
24	San Joaquin Ranch mine	Orange	Do.
25	Buckskin Peak, National district	Humboldt	Nevada.
26	Jarbidge district	Elko	Do.
27	Potosi (Preble) district	Humboldt	Do.*
28	Comstock Lode	Storey	Do.
29	Aurora district	Mineral	Do.
30	Tonopah district	Nye	Do.
31	Ely district	White Pine	Do.
32	Camp Floyd district	Tooele	Utah.*
33	Bingham district	Salt Lake	Do.
34	Park City district	Summit	Do.
35	Gold Springs-State Line district	Iron	Do.
36	San Francisco district	Beaver	Do.
37	Ohio district, Tushar Range	Piute	Do.
38	Marysvale district	do	Do.
39	Silver Reef district	Washington	Do.
40	Iron Mountain district	Iron	Do.
41	Henry Mountains district	Garfield	Do.
42	Temple Mountains and San Rafael Swell	Emery	Do.
43	Thompsons district	Grand	Do.
44	Paradox Valley	San Juan	Do.
45	Monticello and White Canyon districts	do	Do.
46	Blue Mountain	Moffat	Colorado.
47	Maybell district	do	Do.
48	Uravan, Bull Canyon, Paradox Valley, Placerville districts.	Montrose	Do.
49	Slick Rock and Gypsum Valley districts	San Miguel	Colorado.
50	Cortez and Rico districts	Montezuma	Do.
51	La Plata Mountains	La Plata	Do.
52	Liberty Bell mine, Telluride district	San Miguel	Do.
53	Camp Bird mine	Ouray	Do.
54	Vulcan mine	Gunnison	Do.
55	Rifle district	Garfield	Do.
56	Whitehorn district	Fremont	Do.
57	Wet Mountains	Fremont and Custer.	Do.
58	Cripple Creek district	Teller	Do.*
59	Leadville district	Lake	Do.
60	Gilpin County mines	Gilpin	Do.
61	Gold Hill	Boulder	Do.*
62	Baggs area	Carbon	Wyoming.
63	Gas Hills and Crookes Gap districts	Fremont	Do.
64	Converse County district	Converse	Do.
65	Pumpkin Buttes district	Campbell	Do.
66	Crook County district	Crook	Do.
67	Homestake mine	Lawrence	South Dakota.*
68	Edgemont district	Fall River	Do.
69	Eureka district	Yavapai	Arizona.*
70	Walker district	do	Do.*
71	Big Bug and Black Canyon districts	do	Do.*
72	United Verde mine	do	Do.
73	Monument Valley district	Apache	Do.
74	Magma mine	Pinal	Do.
75	Ray district	do	Do.†
76	Old Hat district	do	Do.*
77	Morenci district	Greenlee	Do.
78	Chino mine	Grant	New Mexico.†
79	Grants district	Valencia	Do.
80	La Ventana mesa	Sandoval	Do.
81	Shafter district	Presidio	Texas.*
82	Tri-State district		Missouri, Oklahoma, Kansas.*
83	Antoine Creek district	Clark	Arkansas.*
84	Bauxite district	Pulaski	Do.*
85	Hog Mountain mine	Tallapoosa	Alabama.*
86	Ducktown district	Polk	Tennessee.
87	Tellurium mine	Fluvanna and Goochland.	Virginia.
88	White Hall mine	Spotsylvania	Do.
89	Elizabeth mine	Orange	Vermont.*

*Information obtained from unpublished sources. †Information obtained from company annual reports.

SERIALS

This list gives the abbreviations, full names, and places of publication of serials cited in the bibliography.

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Acad. Nat. Sci. Philadelphia Proc.—Proceedings of the Academy of Natural Sciences of Philadelphia. Philadelphia, Pa.

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Accad. gioenia sci. nat. Catania Atti—Atti dell'Accademia gioenia di scienze naturali in Catania. Catania, Italy.

Agr. Chem. Soc. Japan Jour.—Journal of the Agricultural Chemical Society of Japan. Tokyo.

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Am. Mineralogist—The American Mineralogist. Washington.

Am. Pharmaceutical Assoc. Jour.—Journal of the American Pharmaceutical Association. Washington.

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Jour. Prakt. Chemi—Journal für praktische Chemie. Leipzig, Germany.

Kgl. Norsk Vidensk. Selsk. Förh.—Kongelige Norsk Videnskabers Selskab, Förhandlingar. Oslo.

Metall u. Erz—Metall und Erz, Zeitschrift für Erzbergbau, Metallhüttenwesen und Metallkunde. Stuttgart, Germany.

México Com. Directivo Inv. Recursos Minerales Bol.—Comité Directivo Investigación Recursos Minerales México, Boletin. México.

Mineral Foote-Notes—Mineral Foote-Notes. Philadelphia, Pa.

Mineralog. Mag.—Mineralogical Magazine and Journal of the Mineralogical Society. London.

Mineralog. Mitt.—Mineralogische Mittheilungen. Vienna.

Minería [Peru]—Minería. Lima.

Mines Mag. [Colorado]—Mines Magazine. Golden, Colo.

Mining Jour. [London]—Mining Journal. London.

Mining Mag. [London]—Mining Magazine. London.

Mining Sci. Press—Mining and Scientific Press. San Francisco, Calif.

Natl. Geog. Soc. Contr. Tech. Papers—National Geographic Society Contributed Technical Papers. Washington.

Naturaleza [Mexico]—La Naturaleza. Mexico.

Nature—Nature. London.

Neues. Jahrb. Mineralogie, Monatsh.—Neues Jahrbuch für Mineralogie, Monatshefte. Stuttgart, Germany.

Neues Jahrb. Mineralogie, Geologie u. Palaeontologie, Beil,-Band—Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie, Beilage-Band. Stuttgart, Germany.

New Mexico Agr. Expt. Sta. Bull.—New Mexico College of Agriculture and Mechanical Arts, Agricultural Experiment Station Bulletin. State College, N. Mex.

New York Acad. Sci. Annals—Annals of the New York Academy of Sciences. New York.

Norges Geol. Undersökelse—Norges Geologiske Undersökelse. Oslo.

Norsk geol. tidsskr.—Norsk geologisk tidsskrift. Oslo.

Oceanog. Works Japan Rec.—Records of Oceanographic Works in Japan. Tokyo.

Österreich. Akad. Wiss., math.-nat. Kl.—Österreichische Akademie der Wissenschaften, mathematische-naturalische Klasse. Vienna.

Papier-Zeitung—Papier-Zeitung. Frankfurt am Main, Germany.

Pedology—Pedology. Moscow.

Philos. Mag.—Philosophical Magazine. London.

Phys. Rev.—Physical Review. New York.

Physiol. Rev.—Physiological Reviews. Washington.

Reale Accad. sci. fis. e mat. Napoli Rend.—Rendiconti delle Accademia delle scienze fisiche e matematiche, Società reale di Napoli. Naples, Italy.

Rev. obras sanitarias nación—Revista de obras sanitarias de la nación. Buenos Aires.

Royal Irish Acad. Proc.—Royal Irish Academy Proceedings. Dublin.

Royal Soc. New South Wales Jour. and Proc.—Journal and Proceedings of the Royal Society of New South Wales. Sydney, Australia.

Saratov. gos. Univ. Uchenyye zapiski—Uchenyye zapiski Saratovskogo gosudarstvennogo Universiteta imeni N. G. Chernyshevskogo. Saratov, SSSR.

Science—Science. Washington.

Smithsonian Inst. Ann. Rept.—Smithsonian Institution Annual Report. Washington.

Soc. chim. France Bull.—Bulletin de la Société chimique de France. Paris.

Soc. française minéralogie et crystallographie Bull.—Bulletin de la société française de minéralogie et de crystallographie. Paris.

Soc. géol. Belgique Annales—Annales de la société géologique de Belgique. Liége.

Soc. minéralog. France Bull.—Bulletin de la société minéralogique de France. Paris.

Soc. mineralog. italiana Rend.—Rendiconti della Società mineralogica italiana. Pavia.

Soc. Quim. Peru Bol.—Sociedad Quimica del Peru, Boletin. Lima.

Soil Sci.—Soil Science. Baltimore, Md.

Soil Sci. Soc. America Proc.—Soil Science Society of America, Proceedings. Madison, Wis.

South Dakota Acad. Sci. Proc.—Proceedings of the South Dakota Academy of Science. Vermillion, S. Dak.

South Dakota Agr. Expt. Sta. Bull.; Tech. Bull.—South Dakota State College of Agricultural and Mechanical Arts, Agricultural Experiment Station, Bulletin; Technical Bulletin. Brookings, S. Dak.

Stockholms Högskolas mineralog. inst. Medd.—Meddelanden från Stockholms Högskolas mineralogiska institut. Stockholm.

Sveriges Geol. Undersökning, Ser. C, Årsb.—Sveriges Geologiska Undersökning, Ser. C, Årsbok. Stockholm.

Tokyo Imp. Univ., Coll. Sci. Jour.—Journal of the College of Science, Imperial University of Tokyo. Tokyo.

Univ. Nac. Tucumán, Inst. Geologia y Minería (Jujuy) Pub.—Universidad Nacional de Tucumán, Instituto de Geología y Minería (Jujuy) Publicación. Tucumán, Argentina.

Univ. Szeged. Acta Mineralog. Petrog., Sec. Sci. Nat.—Acta Universitatis Szegediensis, Sectio Scientiarum Naturalium, Acta Mineralogica-Petrographica. Szeged, Hungary.

Univ. Toronto Studies, Geol. Ser.—University of Toronto Studies, Geological Series. Toronto, Canada.

U. S. Bur. Mines Bull.; Inf. Circ.; Rept. Inv.; Tech Paper—U. S. Bureau of Mines, Bulletin; Information Circular; Report of Investigations; Technical Paper. Washington.

U. S. Dept. Agriculture Tech. Bull.—U. S. Department of Agriculture Technical Bulletin. Washington.

U. S. Geol. Survey Bull.; Circ.; Mineral Resources U. S.; Mon.; Prof. Paper; TEI, issued by U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn.—U. S. Geological Survey, Bulletin; Circular; Mineral Resources of the United States; Monograph; Professional Paper; Trace Elements Investigations, issued by U. S. Atomic Energy Commission, Technical Information Service, Oak Ridge, Tenn. Washington.

U. S. Natl. Mus. Bull.; Proc.—U. S. National Museum, Bulletin; Proceedings of the U. S. National Museum. Washington.

Věda Přírodní—Věda Přírodní. Prague.

Virginia Geol. Survey Bull.—Virginia Geological Survey Bulletin. Charlottesville, Va.

Vses. mineralog. obshch. Zapiski.—Zapiski Vsesoyuznogo mineralogicheskogo obshchestva. Moscow-Leningrad.

Washington Div. Mines and Geology Bull.—State of Washington, Department of Conservation and Development, Division of Mines and Geology Bulletin. Olympia, Wash.

Washington Geol. Survey Bull.—Washington Geological Survey Bulletin. Seattle, Wash.

Wyoming Agr. Expt. Sta. Bull.—University of Wyoming, Agricultural Experiment Station Bulletin. Laramie, Wyo.

Wyoming Geol. Survey Bull.—Geological Survey of Wyoming Bulletin. Laramie, Wyo.

Zeitschr. angew. Chemie—Zeitschrift für angewandte Chemie und Zentralblatt für technische Chemie. Berlin-Leipzig, Germany.

Zeitschr. anorg. allg. Chemie—Zeitschrift für anorganische und allgemeine Chemie. Hamburg-Leipzig, Germany.

Zeitschr. Krystallographie u. Mineralogie—Zeitschrift für Krystallographie und Mineralogie. Leipzig, Germany.

Zeitschr. prakt. Geologie—Zeitschrift für praktische Geologie. Halle, Germany.

Zentralbl. Mineralogie—Zentralblatt für Mineralogie, Geologie und Paläontologie. Stuttgart, Germany.

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Aguilero, J. G., 1901, The geographical and geological distribution of the mineral deposits of Mexico: Am. Inst. Mining Metall. Engineers Trans., v. 32, p. 501.

Selenium and its various compounds occur in argentiferous veins in the hornblende andesite of the Sierra de Guanajuato.

Ahlfeld, Friedrich. *See also* Block and Ahlfeld, 1937; Herzenberg and Ahlfeld, 1935.

——— 1954, Los yacimientos minerales de Bolivia: Bilbao, Banco Minero de Bolivia y Corporacion Minera de Bolivia, p. 223–224.

The Pacajake (Hiaco) mine in the Surumi region, 25 kilometers east southeast of Colquechaca, Bolivia, was discovered in 1935. The deposit is a vein in a fracture zone in sandy slate and sandstone of Devonian age. The principal gangue mineral is siderite, with minor amounts of barite, hematite, and calcite. The selenium minerals occur in small lenses in the gangue; the principal ore mineral is blockite (penroseite) which occurs in more or less pure concentric masses resembling native arsenic, or in intimate mixture with clausthalite, tiemannite, and naumannite. The blockite contains 0.22 percent platinum metals. The oxidized ore consists of native selenium, chalcomenite, ahlfeldite, selenolite, and cerussite. Veins of altered eruptive rocks containing traces of gold and platinum metals crop out near the ore vein. The origin of the deposit is unknown. The Pacajake deposit is similar to Tilkerode in the Harz Mountains where platinum, gold, and selenium minerals are also found. About 3,000 kg of selenium minerals have been produced from the Pacajake deposit.

Ahlfeld, Friedrich, and Angelelli, Victorio, 1948, Las especies minerales de la Republica Argentina: Univ. Nac. Tucumán, Inst. Geología y Minería (Jujuy) Pub. no. 458, p. 47–48, 49, 50, 54, 67–69, 70–71, 120–121, 133–134.

Geologic occurrence, mineralogy, and analyses of berzelianite, umangite, naumannite, clausthalite, eucairite, klockmannite, tiemannite, selenolite, chalcomenite, molybdomenite, cobaltomenite, and achavalite are described. At Sierra de Umango, La Rioja Province, umangite, klockmannite, eucairite, berzelianite, clausthalite, tiemannite, and chalcopyrite form veinlets and inclusions in ferruginous calcite gangue. Oxidation of the copper selenides formed chalcomenite and malachite. At Cerro de Cacheuta, Mendoza Province, naumannite, clausthalite, klockmannite, umangite, berzelianite, and achavalite occur in veinlets in porphyry, forming a mechanical mixture once thought to be a polyselenide of lead, silver, copper, iron, and cobalt, called cacheutaite. Oxidation products are selenolite, chalcomenite, molybdomenite, and cobaltomenite. At depth naumannite is the principal ore mineral; below 12 meters depth clausthalite and cerussite are the only minerals found. At Tinogasta, Catamarca Province, umangite, chalcomenite, malachite, and gypsum occur in veinlets. At Sañogasta, La Rioja Province, umangite occurs in veinlets in granite. At Cuesta de los Llantenes, La Rioja Province, umangite and clausthalite occur in calcite veins.

Ahlfeld, Friedrich, and Muñoz Reyes, Jorge, 1938, Mineralogie von Bolivien: Berlin, Verlag von Gebrüder Borntraeger, p. 1, 14–15, 20, 21.

The occurrence of selenium and selenium minerals in Bolivia is described. Minerals include clausthalite, naumannite, umangite, and blockite, which occur at Pacajake.

——— 1939, Die Bodenschätze Boliviens: Berlin, Verlag von Gebrüder Borntraeger, p. 128–129.

The selenium vein at Pacajake, Bolivia is described.

——— 1955, Las especies minerales de Bolivia: Bilbao, Banco Minero de Bolivia, 3d ed., p. 20, 22, 27, 40, 68–69, 98, 131–133.

Descriptions of the mineralogy and occurrence at the Pacajake (Hiaco) mine, Colquechaca, Bolivia, of native selenium, naumannite, tiemannite, clausthalite, penroseite (blockite), selenolite, chalcomenite, ahlfeldite, molybdomenite, lead selenate, and hydrated selenite of iron.

Alber, H. K., and Harand, Josef, 1939, Gravimetric microdetermination of selenium in organic compounds: Franklin Inst. Jour., v. 228, p. 243–250.

Description of procedure for analyzing selenium in organic compounds of which it is a major constituent.

Allchin, J. P. *See* Friend and Allchin, 1941.

Allen, F. B., 1900, Tellurium in the ores of the Hauraki goldfields: Australasian Inst. Mining Engineers Trans., v. 7, no. 87, p. 94–98.

Selenium was detected in auriferous silver sulfide ore in quartz gangue at Great Barrier, New Zealand.

Ancel, Louis, 1919, Le sélénium et ses propriétés et applications actuelles: Chimie et industrie, v. 2, no. 3, p. 245–259.

Uses and properties of various forms of selenium, such as amorphous, crystalline, and colloidal are described.

Ancizar-Sordo, Jorge, 1947, Occurrence of selenium in soils and plants of Colombia, S. A.: Soil Sci., v. 63, no. 6, p. 437–438.

Soils in the Leiva district, State of Boyacá, Colombia, are high in selenium. All plants grown on these soils are high in selenium, indicating that the selenium is in a form readily available to plants.

Anderson, R. G. *See* Peterson and others, 1957.

Angelelli, Victorio. *See also* Ahlfeld and Angelelli, 1948.

——— 1950, Recursos minerales de la República Argentina; 1. Yacimientos metalíferos: [Buenos Aires] Inst. Nac. Inv. Cienc. Nat. Rev., v. 2, p. 481–483.

Thin irregular veins of selenium minerals are found at Tinogasta, Catamarca; Sierra de Umango, Cuesta de los Llantenes, and Sañogasta, La Rioja; and Cerro de Cacheuta, Mendoza. The deposits are thin veins and stringers of umangite, klockmannite, eucairite, clausthalite, tiemannite, and naumannite in calcite gangue. Malachite and chalcomenite are found also, and are believed to be alteration products of umangite.

Atterberg, A., 1874, Om ett selenhaltigt mineral från Falu grufva: Geol. fören. Stockholm Förh., v. 2, p. 76–78.

Analyses of lead bismuth selenide mineral from Falun are given.

Bancroft, Howland, 1914, The ore deposits of northeastern Washington, including a section on the Republic mining district, by Waldemar Lindgren and Howland Bancroft: U. S. Geol. Survey Bull. 550, p. 24, 148–150.

In the Republic district, veins of quartz, adularia, and calcite in andesites and lake beds of Tertiary age and in porphyritic rocks intrusive into these formations contain narrow concentric dark bands consisting of finely distributed tetrahedrite, chalcopyrite, native gold, and selenium in an unknown form. An analysis of a gold-selenium ore from the Republic mine gave 4.36 percent gold and 2.62 percent selenium. After free gold was eliminated by treating the ore with an alkaline sulfide solution, the gold-selenium ratio was 2:3, suggesting the presence of a gold selenide mineral with the formula Au_2Se_3. Gold and selenium appear to be intimately associated in the ore, but it is not known whether they constitute an integral substance or are otherwise associated. No definite selenium minerals could be identified in the ore, although small crystals of pyramidal habit giving a reaction for selenium were found. The authors suggested that they may be a selen-antimonide of silver, analogous to rittingerite.

Bannister, F. A., and Hey, M. H., 1937, The identity of penroseite and blockite: Am. Mineralogist, v. 22, p. 319–324.

Specimens of penroseite from Colquechaca, Bolivia, and blockite from the Hiaco mine, Bolivia, were studied. They were thought to be different minerals because blockite contained less lead and more selenium than penroseite. X–ray studies show that both minerals are intergrown with naumannite and variations in lead and silver content are due to admixture with naumannite. Penroseite and blockite may be regarded as identical minerals, the true composition of which is still uncertain.

Bartlett, F. L., 1889, Some notes on the rarer elements found in the Leadville sulphurets: Eng. Mining Jour., v. 48, p. 342–343.

Low-grade sulphurets from the Iron Silver mine contained selenium, cadmium, thorium, gallium, indium, mercury, antimony, and arsenic. The ores were heavy zinc sulphurets containing 35 percent zinc and 6 percent lead.

Bastin, E. S., 1923, Silver enrichment in the San Juan Mountains, Colorado: U. S. Geol. Survey Bull. 735–D, p. 65–129.

Some selenium and tellurium are present in the matte obtained from smelting the concentrates from the Liberty Bell mine near Telluride, but no selenium or tellurium minerals have been recognized in the ores. The ore veins are late Tertiary fissure veins in Tertiary volcanic rocks. The ore consists of sphalerite, galena, pyrite, chalcopyrite, tetrahedrite, pearcite, argentite, native silver, and an unidentified black mineral in quartz and calcite gangue. Gold is present in the ore but was not observed.

Bastin, E. S., and Laney, F. B., 1918, The genesis of the ores at Tonopah, Nevada: U. S. Geol. Survey Prof. Paper 104, p. 17–18, 46.

The mineral combination in which selenium occurs is not known, but it is believed to be associated with gold and silver in electrum. Selenium was found in pannings consisting mostly of electrum from ore in the West End mine.

Pannings from heavy sulfide ore contained 2.56 percent selenium. Five analyses of ores, concentrates, and bullion containing selenium are given.

Bateman, A. M., 1927, Ore deposits of Rio Tinto (Huelva) district, Spain: Econ. Geology, v. 22, p. 569–614.

Umangite occurs as a primary ore mineral at Rio Tinto. Three unidentified minerals account for the presence of silver, bismuth, nickel, cobalt, antimony, and selenium in the ore. Ore deposits of the Rio Tinto type, which are of replacement origin, are characterized by—large bodies of massive pyrite ores in schistose or sheared rock, associated with igneous intrusions; the minerals pyrite, chalcopyrite, sphalerite, galena, quartz; usually barite and arsenopyrite; absence of high temperature minerals; scarcity of gangue minerals; presence of gold and silver; small amounts of less common metals such as bismuth, selenium, and antimony; lenslike form; association of sericitized rocks; original deep burial; and relatively old age.

Bauerle, L. C. *See* Everett and Bauerle, 1957.

Bear, F. E., 1955, Chemistry of the soil: New York, Reinhold Pub. Corp., p. 72, 280.

Seleniferous areas of the United States, and the form and behavior of selenium in soils and vegetation are briefly described.

Bearse, A. E. *See* Waitkins and others, 1942.

Beath, O. A. *See also* Trelease and Beath, 1949.

——— 1936, Selenium in native range plants occurring on soils derived from Permian and Triassic(?) sediments: Science, v. 83, p. 104.

Selenium indicator plants were found growing on soils derived from two sandstone members of the Chugwater formation in central Albany County, Wyoming, one a sandstone member near the middle of the formation, and the other a limy sandstone in the basal portion, equivalent to the "Embar" of central Wyoming. The average selenium content of a composite sample was 2.4 ppm; one sample from the middle sandstone member gave 10 ppm. selenium.

——— 1937, The occurrence of selenium and seleniferous vegetation in Wyoming; Pt. 2, Seleniferous vegetation of Wyoming: Wyoming Agr. Expt. Sta. Bull. 221, p. 29–64.

Sources of selenium available to plants are limonite concretions, iron pyrites, marcasite, carbonaceous shales, buried alkali beds, bentonite, jarosite, lignite, phosphate rock, ferruginous sandstone, and limy sandstone. Experiments on the distribution and form of selenium in plants and soils are described. The form of selenium in soils derived from most formations in Wyoming is insoluble and not available to most vegetation. Soils derived from the Morrison formation are toxic.

——— 1943, Toxic vegetation growing on the Salt Wash sandstone member of the Morrison formation: Am. Jour. Botany, v. 30, no. 9, p. 698–707.

Native vegetation growing on the Morrison formation in southeast Utah and southwest Colorado is generally seleniferous. The shales, sandstones, and overlying alluvial wash contain selenium, some of which is in a form available to all types of vegetation. No correlation exists between the amount of selenium in the rocks and the amount in the plants growing on them. Selenium concentrations are highest in the Salt Wash member of the Morrison formation, particularly in the uranium-vanadium ore zones. The origin of selenium is believed to parallel that of vanadium and other trace elements in the Salt Wash member. A study was made of the selenium content of the uranium-vanadium ores, shales, alluvial wash, and vegetation in the Thompsons district, Utah.

Beath, O. A., and Eppson, H. F., 1947, The form of selenium in some vegetation: Wyoming Agr. Expt. Sta. Bull. 278, 15 p.

Unrelated plant species rooted in the same soil absorb and concentrate selenium in several different chemical forms and follow a consistent pattern in the forms of selenium they contain. *Astragalus*, *Stanleya*, and certain cereal grains yield only organic selenium; *Aster*, *Atriplex*, and *Xyllorhiza* yield only inorganic selenate; certain native grasses yield both inorganic and organic selenium. It is not known what influence the form of selenium in the soil may exert on the form of selenium in plants. Usually 50 percent or more of the selenium in accumulator plants is water soluble, so that the decay of such plants can return a significant amount of available selenium, both organic and inorganic, to the soil.

Beath, O. A., and Gilbert, C. S., 1936, Selenium-bearing vegetation during late Cretaceous time: Science, v. 84, no. 2187, p. 484–485.

Leafy carbonaceous seams in shales of the continental portion of the Medicine Bow formation of Cretaceous age in southern Albany County, Wyo., contain over 150 ppm selenium. The concentration of selenium in carbonaceous material is confined to the top part of the seams where skeletal leaves and other vegetable matter are still recognizable. These data confirm the authors' theory of vegetative enrichment of selenium through cycles of growth and decay of highly seleniferous native plants.

Beath, O. A., Draize, J. H., and Gilbert, C. S., 1934a, Plants poisonous to livestock: Wyoming Agr. Expt. Sta. Bull. 200, p. 5–84.

The toxic nature of seleniferous plants grown on shales of the Benton, Niobrara, Steele, and Pierre formations of Cretaceous age in Wyoming is discussed. Seleniferous plants are pictured and described.

Beath, O. A., Eppson, H. F., and Gilbert, C. S., 1935, Selenium and other toxic minerals in soils and vegetation: Wyoming Agr. Expt. Sta. Bull. 206, 55 p.

Seleniferous formations of Cretaceous and Eocene ages in Wyoming are described. The source of the selenium in these formations is believed to be volcanic material from which the sediments were derived, for there was extensive volcanic activity and selenium was a primary constituent of the magma from these volcanoes. Methods of analysis for selenium in plants and soils are given, and absorption of selenium by vegetation, highly seleniferous drainage basins known as poison basins, and poisonous plant groups are discussed. Pyrite concretions from the Niobrara formation contained up to 548 ppm selenium and averaged from 250 to 350 ppm selenium. Concretions from the Benton, Steele, Lewis, Mesaverde, and Morrison formations contained 0.5 to 4.1 ppm selenium. Selenium in such concretions is almost totally insoluble.

Beath, O. A., Eppson, H. F., and Gilbert, C. S., 1937a, Selenium distribution in and seasonal variation of type vegetation occurring on seleniferous soils: Am. Pharmaceutical Assoc. Jour., v. 26, no. 5, p. 394–405.

Report on studies of the form of selenium in soils and plants, and the growth behavior of and distribution of selenium in plants grown on seleniferous soils.

Beath, O. A., Gilbert, C. S., and Eppson, H. F., 1937b, Selenium in soils and vegetation associated with rocks of Permian and Triassic age: Am. Jour. Botany, v. 24, no. 2, p. 96–101.

Selenium is found to be a primary constituent of stratigraphically equivalent rocks of Permian and Triassic age in Wyoming, including the Phosphoria, Dinwoody, "Embar", and basal Chugwater formations. One of the source materials from which these formations were derived was selenium-bearing magma from volcanoes active during Permian and Triassic time. Analyses are given of phosphate and selenium content of the Phosphoria formation from several places in Wyoming. There is no correlation between phosphate and selenium; selenium is distributed unevenly and its content is highly variable, ranging from 5.2 to 200 ppm at Rocky Point. Lighter colored phosphate rock is lower in selenium content than dark colored material. No selenium was found in crude oils from Fremont County.

——— 1939a, The use of indicator plants in locating seleniferous areas in western United States; Pt. 1, General: Am. Jour. Botany, v. 26, no. 4, p. 257–269.

The presence of selenium in the soil may have been caused by the erosion of igneous rocks containing seleniferous material or the absorption of selenium from brackish water or shallow basins by marine organisms or plants. In some places selenium occurs in carbonaceous beds, but not in carbonate beds of the same formations. Geographical and geological occurrences of 32 species of native selenium indicator plants are reported. The origin and form of selenium in soil were studied. Selenium in the soil is believed to be in a highly insoluble form, and the number of plants capable of absorbing it is small compared with the total forage cover.

——— 1939b, The use of indicator plants in locating seleniferous areas in western United States; Pt. 2, Correlation studies by States: Am. Jour. Botany, v. 26, no. 5, p. 296–315.

Studies of 563 specimens of native plants from Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Texas, and Utah. Species of known indicator plants were given special attention. The studies demonstrated that many formations of late Paleozoic to Quaternary age, including igneous and sedimentary rocks, support seleniferous vegetation.

——— 1940, The use of indicator plants in locating seleniferous areas in western United States; Pt. 3, Further studies: Am. Jour. Botany, v. 27, no. 7, p. 564–573.

In a study of the distribution of types of selenium-bearing plants, seleniferous vegetation from Arizona, California, Colorado, Montana, New Mexico, North Dakota, Texas, Utah, and Wyoming was analyzed. Data were obtained on seleniferous areas in Stoddard County, Mo., and Dryden, Tex., where no selenium indicator plants had been reported. The Dakota and Morrison formations were found to be seleniferous over large areas.

Beath, O. A., Gilbert, C. S., and Eppson, H. F., 1941, The use of indicator plants in locating seleniferous areas in western United States; Pt. 4, Progress report: Am. Jour. Botany, v. 28, no. 10, p. 887–900.

Further studies on the occurrence and classification of selenium indicator plants are reported. From formations not previously tested in Arizona, California, Colorado, Montana, Nebraska, New Mexico, North Dakota, South Dakota, Texas, Utah, and Wyoming, 407 analyses were made of indicator plants.

Beath, O. A., Hagner, A. F., and Gilbert, C. S., 1946, Some rocks and soils of high selenium content: Wyoming Geol. Survey Bull. 36, 23 p.

Five tuffs from Lysite poison draw, Fremont County, Wyo., contained 12.5, 29, 112, 175, and 187 ppm selenium. In the last three, 84 to 96 percent of the total was water-soluble selenium, mostly in the form of selenate. Tertiary sandstone in the Poison Butte area, Carbon County, contained 112 ppm selenium, of which 91.4 ppm was water-soluble selenate. Vanadiferous siltstone in the phosphatic shale member of the Phosphoria formation in western Wyoming contained from 188 to 680 ppm selenium and from 0.12 to 2.12 percent vanadium. Selenium showed a positive correlation with the vanadium content of the rock. Phosphatic rocks from the Phosphoria formation contained from a few to 212 ppm selenium. Uranium-vanadium ores and carbonaceous shales also had high selenium content. Vanadiferous rocks contained a high proportion of insoluble selenium in the form of selenite, whereas the tuffs and sandstone contained mostly soluble selenates.

Beath, O. A., Draize, J. H., Eppson, H. F., Gilbert, C. S., and McCreary, O. C., 1934b, Certain poisonous plants of Wyoming activated by selenium and their association with respect to soil types: Am. Pharmaceutical Assoc. Jour., v. 23, no. 2, p. 94–97.

A correlation of seleniferous range plants with the geological formations on which they grow shows that shales of the Niobrara, Steele, Pierre, Morrison, Wasatch, Benton, Hilliard-Cody, Lewis, and Bridger formations, and a dark band of the Dakota formation support seleniferous vegetation.

Becker, G. F., 1888, Geology of the quicksilver deposits of the Pacific slope, with an atlas: U. S. Geol. Survey Mon. 13, p. 385–386.

The Lucky Boy claim, Mt. Baldy district, Piute County, Utah, contains bunches of tiemannite in limestone. One ore body was 4 feet thick. Seventy-six flasks of mercury were produced from this ore, which averaged 10 percent mercury.

Bellini, Raffaello, 1907, Spuren von Selen auf der Vesuvlava von 1906: Zentralbl. Mineralogie, Jahrg. 1907, no. 20, p. 611–612.

Free selenium occurs in association with crusts of sodium chloride on the lava as small connected spots or aureoles surrounding the sodium chloride. Chlorides of potassium and iron were also found with the selenium. (Chem. Abs., v. 2, p. 249.)

Benard, Frederick, 1933, Electrolytic copper refinery of Ontario Refining Company, Limited, at Copper Cliff, Ontario: Am. Inst. Mining Metall. Engineers Trans., v. 106, p. 369–397.

Typical tank house slimes from ores of the Frood and other mines in the Sudbury district have an average content of 15.03 percent selenium. Refining process and equipment are described.

Benard, Frederick, 1944, Recovery of selenium and tellurium at Copper Cliff, Ontario: Am. Inst. Mining Metall. Engineers Trans., v. 159, p. 521–529; Tech. Paper 908, 9 p., 1938.

Description of selenium plant and recovery process used by the Ontario Refining Company.

Bergenfelt, Sven, 1953, Om förekomst av selen i Skelleftefältets sulfidmalmer: Geol. fören. Stockholm Förh., v. 75, no. 37, p. 327–359. [Swedish, English summary.]

Analyses of ores, minerals, and concentrates to determine the distribution of selenium in sulfide ores of the Skellefte district show that pyrite, pyrrhotite, and sphalerite are generally low in selenium; chalcopyrite is richer than pyrite; arsenopyrite and galena are generally high in selenium. No correlation was found between copper, arsenic, or zinc and selenium; correlations were found between bismuth and antimony and selenium. Study included the Boliden, Åkulla, Renström, Långdal, Kristineberg, Rävliden, eastern Bjurfors, Laver, Adak, and Lainijaur deposits. Ores from the Boliden mine are generally richer in selenium than those of the other mines. The largest concentration of selenium was found in the quartz-tourmaline veins, where sulfo minerals and tellurides with considerable amounts of selenium occur. Arsenopyrite ore is also rich in selenium; pyrite ore is low in selenium. At Boliden the average selenium content of pyrite was from 0.004 to 0.03 percent; of galena, 1 to 1.5 percent; of chalcopyrite, 0.07 to 0.14 percent; of sphalerite, 0.03 to 0.09 percent; of arsenopyrite, 0.04 to 0.16 percent; of pyrrhotite, 0.002 to 0.007 percent. Variations in selenium content of a given mineral from various deposits are attributed to the great differences in selenium content of the ores, as regulated by the selenium content of the mineralizing solutions.

Berman, Harry. *See* Palache and others, 1944.

Berry, L. G. *See* Peacock and Berry, 1940.

Bertrand, Émile, 1882, Sur la molybdoménite (sélénite de plomb), la cobaltoménite (sélénite de cobalt), et l'acide sélénieux de Cacheuta (La Plata): Soc. minéralog. France Bull., v. 5, p. 90–92.

Molybdomenite and cobaltomenite, selenites of lead and cobalt, formed as alteration products of selenides, are associated with chalcomenite, copper selenite, at Cerro de Cacheuta, Mendoza, Argentina. Lead carbonate and white needles believed to be selenious acid, selenolite, are found in veins in molybdomenite and are believed to be alteration products of molybdomenite.

Berzelius, J., 1818, Des recherches sur un nouveau corps minéral trouvé dans le soufre fabriqué à Fahlun: Annales chimie et physique, ser. 2, v. 9, p. 225–267. [Also in Jour. Chemie u. Physik, v. 23, p. 309–344, 430–484, 1818 (German).]

Describes the chemistry and chemical compounds of selenium separated from sulfur from the Falun mine, Sweden.

Bethke, P. M., 1956, Sulfo-selenides of mercury [abs.]: Geol. Soc. America Bull., v. 67, no. 12, pt. 2, p. 1671.

Sulfoselenides of mercury form a complete isomorphous series defined by the diadochy of sulfur and selenium which is denoted as the metacinnabar series, including the minerals metacinnabar, onofrite, and tiemannite. The series is found in its entirety at Marysvale, Utah. Selenium is unable to replace sulfur in the cinnabar structure except for possible trace amounts. It is proposed that the distribution of selenium between cinnabar and metacinnabar is related to differences in bond type. Some crystallographic data are given.

Beyschlag, F., Krusch, P., and Vogt, J. H. L., 1914, The deposits of the useful minerals and rocks, their origin, form, and content: London, MacMillan and Co., v. 1, p. 166–167; v. 2, p. 589.

Selenium is closely related to sulfur and it almost always accompanies sulfur. Types of deposits in which selenium occurs are: (a) native sulfur in volcanic districts; (b) sulfide lodes as at Lehrbach, Zorge, and Tilkerode in the Harz; (c) copper shales; (d) pyrite deposits as at Fahlun, Rio Tinto, and Rammelsberg. In most deposits the sulfur-selenium ratio is 10,000 : 1. Although tellurium tends to occur in separate deposits, it is found with selenium in telluride lodes of the young gold-silver group. In such cases about 1.5 percent of the tellurium is replaced by selenium. The gold-selenium deposits of Radjang Lebong, Sumatra, are described.

Bianchi, Umberto, 1919, Il selenio: Milan, Ulrico Hoepli, 136 p.

Describes forms, properties, and uses of selenium.

Biltz, Wilhelm. *See* Geilmann and Biltz, 1931.

Block, Hans, 1937, Das Selenvorkommen von Pacajake in Bolivien: Metall u. Erz, v. 34, no. 10, p. 237–238.

Clausthalite, blockite (penroseite), and other selenides occur in a vein with a gangue of limonite, barite, and hematite at the Hiaco silver mine, near Colquechaca, Bolivia. Analysis of blockite shows it to contain copper and nickel with minor amounts of cobalt, iron, lead, mercury, silver, and platinum.

Block, Hans, and Ahlfeld, Friedrich, 1937, Die Selenerzlagerstätte Pacajake, Bolivia: Zeitschr. prakt. Geologie, v. 45, p. 9–14.

Selenium minerals occur in a vein along a fault area in the Hiaco silver mine in the Pacajake anticline in the central Bolivian cordillera, 30 km from Colquechaca, Bolivia. The chief mineral is blockite (penroseite), a nickel-copper selenide, with some clausthalite, chalcomenite, naumannite, native selenium, and other selenium minerals, in a gangue of barite, siderite, hematite, and calcite.

Bodenbender, G., 1902, Comunicaciones mineras y mineralógicas. 8. Criaderos de seleniuro de cobre, de sulfuro de cobre y de sulfuro de plata: Acad. Nac. Cienc. Córdoba Bol., v. 17, p. 368–371.

At Tinogasta, Catamarca Province, Argentina, umangite mixed with sulfides and gypsum, occurs in thin layers in stratified calcitic-silicic gangue.

Borgström, L. H., 1914–15, The melting and boiling points of metalloid-sulfide, selenide, and telluride minerals: Finska vetensk.-soc. Öfversikt av Förh. (A), v. 57, no. 24, 13 p.

The behavior of the minerals studied is described in detail, and values of melting points are given as: realgar, 310; orpiment, 320; kermesite, 517; stibnite, 546; tetradymite, 600; guanajuatite, 690; bismuthinite, 718° C. The occurrence of the minerals is discussed, and by tabulating their melting points and modes of occurrence it is shown that in a general way those with the lowest melting points form under conditions of low temperature and pressure, near the surface of the earth, while the higher the melting point becomes the more the mineral is found in deep-seated rocks. (Chem. Abs., v. 9, p. 2364.)

Botinelly, Theodore, 1956, Ore mineralogy, *in* Geologic investigations of radioactive deposits—semi annual progress report for December 1, 1955, to May 31, 1956: U. S. Geol. Survey TEI-620, issued by U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn., p. 117–119.

Studies of uranium-vanadium deposits in the Salt Wash sandstone member of the Morrison formation indicate that the deposits are similar in mineralogy. Metallic minerals associated with the ore are pyrite, marcasite, and galena. Many of the deposits contain clausthalite, which forms thin zones or layers of limited extent.

Braddock, William. *See* Thompson, M. E., and others, 1956.

Bradley, W. W., 1916, Selenide of silver: Mining Sci. Press, v. 112, p. 741.

A dull black mineral was found closely associated with argentite in a quartz vein on the ninth level of the De Lamar mine, Owyhee County, Idaho. The author provisionally identified the mineral as aguilarite, a silver sulfoselenide.

——— 1918, Quicksilver resources of California: California State Mining Bur. Bull. 78, p. 27–28, 193.

Tiemannite was found in large masses in association with cinnabar in the Abbott mine, Lake County, in the Socrates mine, Sonoma County, and in Orange and Santa Clara Counties.

Bright, M. S. *See* Hillebrand and others, 1953.

Brooker, E. J. *See* Robinson, C. S., and Brooker, 1952.

Brown, F. C., 1914, The crystal forms of metallic selenium and some of their physical properties: Phys. Rev., ser. 2, v. 4, p. 85–98.

A large number of crystals of metallic selenium, some of which were of large size, were formed by sublimation. The larger crystals were formed at higher temperatures. All were believed to belong to the hexagonal system. The properties, reaction to light, conductivity, and effects of mechanical pressure of the crystals are described.

——— 1915, Isolated crystals of selenium of the second and fifth systems, and the physical conditions determining their production: Phys. Rev., ser. 2, v. 5, p. 236–237.

Hexagonal and monoclinic artificial crystals of selenium are described.

Brown, G. F., and others, 1952, Geologic reconnaissance of the mineral deposits of Thailand: U. S. Geol. Survey Bull. 984, p. 82–87.

Disseminated sulfide replacement ore from the Nong Phai lead-zinc mine, Kanchanaburi, western Thailand, contains 0.05 percent selenium.

Brown, G. V., 1916, Composition of the selensulfur from Hawaii: Am. Jour. Sci., ser. 4, v. 42, p. 132–134.

Analysis of a specimen of selensulfur from Kilauea, Hawaii, gave 5.18 percent selenium and 94.82 percent sulfur. Lava which had been discarded as showing practically no selensulfur contained 0.07 percent selenium and 3.32 percent sulfur. Also present were silica, phosphorous, iron, aluminum, titanium, calcium, magnesium, sodium, and potassium. No tellurium or arsenic were found. Such a small amount of selenium was found that the mineral was considered only a variety of sulfur, and "seleniferous sulfur" was suggested as a more appropriate name for the mineral.

Brown, G. V., 1917, The composition of seleniferous sulfur: Am. Mineralogist, v. 2, p. 116–117.

Seven specimens of seleniferous sulfur contained selenium in the following uniform but small amounts: from Kilauea, 5.18 percent; from New Zealand, 0.298 and 0.195 percent; from Lipari Island, 0.285 and 0.272 percent; from Sicily, 0.070 and a trace.

Brown, I. C. *See* Miller and Brown, 1938.

Brown, J. C., and Dey, A. K., 1955, India's mineral wealth: 3d ed., Bombay, New York, Oxford University Press, p. 301–302.

There is reason to suspect the presence of selenium in the copper ores of Singhbhum and in the lead-zinc-copper ores of Bawdwin, in the Shan States, but in neither case are analyses available of the waste products in which it may have accumulated during their treatment.

Brush, G. J., 1881, On American sulpho-selenides of mercury; with analyses of onofrite from Utah, by W. J. Comstock: Am. Jour, Sci., ser. 3, v. 21, no. 124, p. 312–316.

Specimens of sulfoselenide of mercury from Marysvale, Utah, were identified as onofrite. Compositions of several sulfur-selenium-mercury minerals are compared. Sulfoselenides of mercury form an isomorphous series from metacinnabarite, which contains no selenium, through guadalcazarite, onofrite, and tiemannite, which contains very little sulfur. Sulfoselenides of mercury are found at Culebras, San Onofre, and Guadalcazar, Mexico, and at Marysvale, Utah.

Burkart, J., 1866, Über einige mexicanische Mineralien; Chlorselenquecksilber; Schwefelselenzinkquecksilber: Neues Jahrb. Mineralogie, Geologie u. Palaeontologie, Jahrg. 1866, p. 411–417.

Descriptions of selenium minerals from Guadalcazar, Mexico, are given.

——— 1872, Ueber den Guadalcazarit: Mineralog. Mitt., Jahrg. 1872, no. 4, p. 243–244.

The mineral guadalcazarite, from Guadalcazar, Mexico, is described.

Burris, Robert. *See* Franke and others, 1936.

Buryanova, E. Z., 1956, Ferroselite: Vses. mineralog. obshch. Zapiski, v. 85, no. 3, p. 286–291. [Russian.]

Ferroselite was first observed in Middle Devonian sandstone of the Tuvinsk Autonomous Territory associated with barite, pyrite, sphalerite, chalcopyrite, and a calcite-laumontite cement of the quartz sand grains. Its occurrence in clastic portions of effusive rock fragments and pelites indicates enrichment of selenium from highly dispersed selenium in sediments. Widespread Paleozoic acidic effusive rocks must have been the source of the selenium. The mineralogy is described. (Chem. Abs., v. 51, col. 2477.)

Buryanova, E. Z., and Komkov, A. I., 1955, A new mineral—ferroselite: Akad. Nauk SSSR Doklady, v. 105, p. 812–813. [Russian.]

Ferroselite occurs associated with chalcopyrite and pyrite, in disseminations in calcite, cementing polymict sandstones and in coarse fragmental pelites in Middle Devonian deposits of the Tuvinsk Autonomous Territory. The composition of ferroselite is $FeSe_2$, and it is found in small prismatic crystals of 0.2 to 0.5 mm in length and 0.1 mm in cross section. (Chem. Abs., v. 50, col. 9239.)

Buryanova, E. Z., Kovalev, G. A., and Komkov, A. I., 1957, The new mineral cadmoselite: Vses. mineralog. obshch., Zapiski, v. 86, no. 5, p. 626–628. [Russian.]

A new cadmium selenide mineral was found in association with ferroselite, clausthalite, native amorphous selenium, cadmium-bearing sphalerite, pyrite, and other minerals. The mineral, named cadmoselite, forms fine disseminations in the cement of sandstone. Mineralogic and crystallographic data are given.

Butler, B. S., 1913, Geology and ore deposits of the San Francisco and adjacent districts, Utah: U. S. Geol. Survey Prof. Paper 80, p. 95, 186.

The presence of selenium was detected in ore from the Golden Reef mine on the east side of the San Francisco Range. The primary ore mineral is galena with small amounts of pyrite. The ore is valuable chiefly for its gold, which is present in an unknown form, but it is probably not free. The form in which selenium is present has not been determined.

Butler, B. S., Loughlin, G. F., Heikes, V. C., and others, 1920, The ore deposits of Utah: U. S. Geol. Survey Prof. Paper 111, p. 106–108, 144–145, 152, 347, 542, 543, 544, 551–552, 555–556, 592, 593.

Selenium occurs in small amounts in many of the ore deposits of Utah. It collects in bullion and some of it is probably recovered in refining. In 1913, blister copper from the Garfield smelter, which derived most of its ore from the Bingham district, contained an average of 56 pounds of selenium per 100 tons of blister copper. Selenium is present in the gold-silver ores of the Gold Springs-State Line region and the Tushar Range, in mercury ore of the Lucky Boy mine near Marysvale, and is widely distributed in the sandstone deposits in southeastern Utah. The only apparently primary silver mineral recognized in banded quartz veins in the Tushar Range has a silver-white metallic luster and contains both selenium and tellurium. The mineral contains free gold in minute fissures, and possibly gold is one of its essential constituents. The rich gold ore of the Bully Boy and Webster mine in the Ohio district is in part native and in part probably combined with silver as telluride and selenide. Tiemannite and onofrite were found in a replacement deposit from 2 to 8 inches thick in limestone at the Lucky Boy mine, Mount Baldy district. The silver ore of the Silver Reef sandstone deposit carries selenium, which would suggest that part of the silver at least may be combined in some form with selenium.

Byers, H. G. *See also* Edgington and Byers, 1942; Lakin and Byers, 1941, 1948; Lakin and others, 1938; Miller and Byers, 1935; Robinson, W. O. and others, 1934, Slater and others, 1937; Williams and Byers, 1934, 1935a, b, 1936; Williams and others, 1940, 1941.

Byers, H. G., 1934, Selenium, vanadium, chromium, and arsenic in one soil: Indus. Eng. Chemistry, News Ed., v. 12, p. 122.

Two samples of Pierre loam contained 2 ppm selenium, 460 and 470 ppm vanadium, and wheat grown on the soil contained 25 ppm selenium and 9 ppm vanadium.

——— 1935, Selenium occurrence in certain soils in the United States, with a discussion of related topics: U. S. Dept. Agriculture Tech. Bull. 482, 47 p.

Results of a reconnaissance survey of seleniferous soils in Wyoming, Montana, South Dakota, Colorado, Nebraska, Kansas, Oklahoma, Utah, New Mexico, and Arizona are given. Large areas of South Dakota were sampled and contour maps were prepared to detect the distribution of selenium in the soils. Investigations were made of selenium in Pierre shale in Nebraska and South Dakota, in water, and in pyrites. The author concluded that the source of selenium is sulfide minerals in the soil parent materials, and the selenium content of vegetation is dependent on the quantity and distribution of selenium and the amount of available sulfur in the soil.

——— 1936, Selenium occurrence in certain soils in the United States, with a discussion of related topics, second report: U. S. Dept. Agriculture Tech. Bull. 530, 78 p.

Analyses of soils and vegetation in Nebraska, South Dakota, and Wyoming, south and southwest of the Black Hills; in Mesa, Montrose, and Delta Counties, Colo., near the Grand Valley and Uncompahgre irrigation projects; in a large area of western Kansas; and in areas of Montana are given. These show that seleniferous soils are derived from the Pierre and Niobrara formations, and that irrigation or drainage removes the selenium from the soil. The effects of rainfall, relation of selenium in the soil to that in the plant, selenium poisoning of water, and miscellaneous analyses of soils and vegetation of Wyoming, Canada, New Mexico, Texas, North Carolina, Puerto Rico, and Cuba are discussed.

——— 1937a, The origin, distribution, and effects of selenium: Soil Sci. Soc. America Proc., v. 1, p. 327.

Selenium is of general distribution throughout all soils, as it is through all igneous rocks. The source of exceptional quantities of selenium in soils derived from shales was seleniferous volcanic emanations deposited in seas of the Cretaceous or other periods when shales were produced.

——— 1937b, Selenium in Mexico: Indus. Eng. Chemistry, Indus. Ed., v. 29, no. 10, p. 1200–1202.

High selenium content of soils near the town of Irapuato in the Guanajuato River valley, State of Guanajuato, is caused by selenium-bearing waste from the Guanajuato silver mines. Slimes left after silver and gold extraction were dumped in the canyon and during periods of inundation were deposited over the flood plain of the stream. Ore from the Sirena mine, Guanajuato, contained 16 ppm selenium; slimes contained 4.6 ppm selenium.

——— 1938, Selenium in meteorites: Indus. Eng. Chemistry, News Ed., v. 16, p. 459.

Eighteen meteorites of various compositions were examined for selenium content. All stony meteorites—stone, chondrite, pallasite, and mesosiderite—examined contained from 3 to 15 ppm selenium. Iron alloy samples from octahedrite meteorites contained no selenium; concretions of troilite (iron sulfide) found in octahedrite meteorites contained 23 ppm and 200 ppm selenium.

Byers, H. G., and Knight, H. G., 1935, Selenium in soils: Indus. Eng. Chemistry, Indus. Ed., v. 27, p. 902–904.

The quantity of selenium in vegetation grown upon seleniferous soil depends on the concentration of selenium in the soil, plant species, composition of soil, moisture, stage of development of plant, and part of plant examined.

Byers, H. G., and Lakin, H. W., 1939, Selenium in Canada: Canadian Jour. Research, v. 17, sec. B, p. 364–369.

Three hundred analyses of shales, soils, and plants collected in Cretaceous areas of Alberta, Saskatchewan, and Manitoba provinces indicate a large area of seleniferous soil. Selenium content of shales varied from 0.3 to 3.0 ppm; soils, from 0.1 to 6 ppm, plants, from 3 to 4190 ppm. Analyses are given.

Byers, H. G., Williams, K. T., and Lakin, H. W., 1936, Selenium in Hawaii and its probable source in the United States: Indus. Eng. Chemistry, Indus. Ed., v. 28, p. 821–823.

Volcanic gas and sublimates of Hawaiian volcanoes are high in selenium; lavas and volcanic ash are low in selenium. Selenium is present in all the soils of Hawaii as insoluble basic ferric selenite. Selenium content of soils varies from 1 to 26 ppm and is higher in soils in areas of higher rainfall. Selenium of Hawaiian soils is derived from volcanic gases or sublimates and is carried down into the soil by rain and held there in a highly insoluble form. The authors conclude that selenium is of volcanic origin and was brought down by rainfall into the Cretaceous seas of the Western United States in which seleniferous shales were formed.

Byers, H. G., 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. Agriculture Tech. Bull. 601, 74 p.

This report contains tables showing the selenium content of soils in Prowers, Kiowa, Cheyenne, Bent, Otero, Crowley, Lincoln, Las Animas, Huerfano, Pueblo, El Paso, and Fremont Counties, Colo.; Colfax, Mora, San Miguel, and Harding Counties, N. Mex.; and parts of Arizona and Utah. Results are given of studies on variations in selenium content of plants, effect of irrigation on selenium, selenium in the Colorado River and in the ocean, selenium in soils of Hawaii and Puerto Rico, and the distribution of selenium in the soil profile.

Čadek, Josef, and Doležal, Jan, 1957, Determination and geochemistry of selenium: [Czechoslovakia] Ustrední ústav geol. Věstník, v. 32, no. 1, p. 28–40 [Czech, English summary.]

Very small amounts of selenium in pyrite were determined. Analyses of 8 pyrites gave 11–72 ppm selenium; of 1 marcasite, 4 ppm; of 1 pyrrhotite, 1.5 ppm; of 1 sphalerite, 67 ppm selenium. (Chem. Abs., v. 51, col. 9422.)

Cahen, Edward, 1919, Selenium: Mineral Foote-Notes, v. 3, no. 5, p. 5–16.

Occurrence, source, chemical and physical properties, and uses of selenium are described.

Cahen, Edward, and Wootton, W. O., 1920, The mineralogy of the rarer metals: 2d ed., London, Charles Griffin and Co., p. 97–106.

Properties, uses, and detection of selenium and selenium minerals are described.

Callaghan, Eugene. *See* Hewett and others, 1936.

Campbell, T. W. *See* McCullough and others, 1946.

Canada, Department of Mines and Technical Surveys, 1952, Canadian mineral industry: Ottawa, p. 71–72.

Canadian selenium occurs in copper sulfide and gold ores; it is produced by two companies.

Canney, F. C. *See* Lovering and others, 1956.

Cannon, H. L., 1952, The effect of uranium-vanadium deposits on the vegetation of the Colorado Plateau: Am. Jour. Sci., v. 250, p. 735–770.

Biogeochemical studies of the relationship of plants to uranium-vanadium deposits were made in the Thompsons district, Grand County, Utah, where uranium ore in the Salt Wash sandstone member of the Jurassic Morrison formation contains unusual concentrations of uranium, vanadium, and selenium. Plants growing near shallow ore deposits accumulate small amounts of these metals. The effects of these metals on plant growth were observed, the ecology of the plants was studied, and the distribution of various species of indicator plants was mapped in detail. A uranium-tolerant flora has been recognized and is characterized by selenium-indicator plants. Where selenium-bearing ore lies at shallow depth and where the geography and rainfall are favorable for plant growth, the distribution of selenium-indicator plants is the same as that of the carnotite ores. Certain species of selenium-indicator plants can be mapped as guides to exploration.

——— 1953, Geobotanical reconnaissance near Grants, N. Mex.: U. S. Geol. Survey Circ. 264, 8 p.

Carbonaceous uranium ore in the Westwater Canyon member of the Jurassic Morrison formation contains a high percentage of selenium and the mapping of selenium-indicating *Astragalus* and *Oryzopsis* plants commonly associated with these deposits is suggested as a method of prospecting for uranium. Selenium-indicator plants apparently do not grow on the Todilto limestone member of the Wanakah formation in the same area, although in places the uranium ore contains sufficient selenium to support such plants.

——— 1954, Botanical methods of prospecting for uranium: Am. Inst. Mining Metall. Engineers Trans., v. 199, p. 217–220.

Botanical methods of prospecting for metalliferous ores are based on the premise that deposits at depth may be reflected chemically in surface vegetation. Uranium is a necessary nutrient for plant growth and therefore is present in all plants. Selenium, which is associated with uranium ores in many areas, is necessary only to certain plants known as selenium-indicator plants. *Astragalus confertiflorus*, *A. preussi var. arctus*, *A. thompsonae*, *A. pattersoni*, *Oryzopsis hymenoides*, and *Aster venusta* are selenium-indicator plants common in uranium districts. They bear a recognizable relationship to carnotite deposits of the southwest and have distinct distribution patterns which depend on the amount of selenium in the ore and the amount required by the plant. In the Thompsons district, Utah, plants were mapped over an area of 6 square miles and 1000 holes were drilled. Of 194 holes drilled in areas supporting the growth of indicator plants, 90 were in mineralized ground. Indicator plants were present in the vicinity of 12 percent of the unmineralized holes, 54 percent of the mineralized holes (including ore holes), and 81 percent of the ore holes. Of 10 orebodies discovered in the Yellow Cat area, 4 would not have been found had it not been for the additional information furnished by indicator plants.

Cannon, H. L., 1956, Advances in botanical methods of prospecting for uranium: Internat. Geol. Cong., 20th, Mexico 1956, Resumenes Trabajos Presentados, p. 359–360.

Mapping the distribution of indicator plants rooted in ore-bearing formations is an effective prospecting method. Distinctive plants requiring selenium or sulfur may indicate associated uranium ores. *Astragalus* plants have delineated ore bodies to depths of 25 meters.

——— 1957, Description of indicator plants and methods of botanical prospecting for uranium deposits on the Colorado Plateau: U. S. Geol. Survey Bull. 1030–M, p. 399–516.

Botanical prospecting by mapping indicator plants is used in semiarid parts of the Colorado Plateau at low altitude. The distribution of indicator plants is controlled by the availability of chemical constituents of the ore, such as selenium, sulfur, and calcium. Plants of the genus *Astragalus* are most useful in prospecting for uranium deposits of high selenium content. Fifty indicator plants usually associated with carnotite deposits and plants tolerant of mineralized ground are described and illustrated.

Cannon, H. L., and Kleinhampl, F. J., 1956, Botanical methods of prospecting for uranium, *in* Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 681–686.

Selenium-indicator plants are used in prospecting for uranium on the Colorado Plateau because the availability of selenium to plants is increased many fold by the presence of carnotite, and the distribution of selenium-indicator plants is controlled by the distribution of carnotite. The most useful plant is *Astragalus pattersoni*, which commonly absorbs several thousand parts per million selenium from uranium ores, and is capable of extracting selenium directly from ore bodies as deep as 75 feet. Prospecting by indicator plants is advantageous where the uranium content is 0.01 percent or more and the selenium content is 0.01 percent or more, if the upper limits of the ore body are not more than 40 feet below the surface.

Cannon, H. L., and Starrett, W. H., 1956, Botanical prospecting for uranium on La Ventana Mesa, Sandoval County, New Mexico: U. S. Geol. Survey Bull. 1009–M, p. 391–407.

Minor amounts of selenium are concentrated in uranium-bearing coal. The ratio of selenium to uranium is very high in mineralized coal, with 600 ppm selenium reported in one sample. Selenium indicator plants associated with sulfur indicator plants were noted on the slope below the outcrop of uranium-bearing coal.

Carlos, G. C. *See* Edwards and Carlos, 1954.

Caron, P. E. *See* Stone and Caron, 1954.

Carstens, C. W., 1941a, Om geokjemiske undersøkelser av malmer: Norsk geol. tidsskr., v. 21, no. 2–3, p. 213–227.

The selenium content and sulfur-selenium ratios of sedimentary and hydrothermal pyrites of the Bymark group of the Trondheim area, Norway, including the Leksdals and Løkken-Grong types, are discussed. The article contains many analyses of ores containing selenium.

——— 1941b, Über sedimentäre Schwefelkiesvorkommen: Kgl. Norsk Vidensk. Selsk. Förh., v. 14, p. 120–122.

Sedimentary pyrite of the Leksdals type contains no selenium; hydrothermal pyrite of the Løkken-Grong type contains more than 10 ppm selenium.

——— 1941c, Zur Geochemie einiger norwegischen Kiesvorkommen: Kgl. Norsk Vidensk. Selsk. Förh., v. 14, no. 10, p. 36–39.

The pyrite in the Bymark group of the Trondheim area is of two types: the Leksdals type of sedimentary origin, and the Løkken-Grong type of hydrothermal origin. Pyrite of the Leksdals type contains less than 0.1 percent copper and is relatively selenium free. Pyrite of the Løkken-Grong type customarily contains a minimum of 0.5 percent copper and a significant amount of selenium, averaging from 20 to 30 ppm. A table gives copper, sulfur, and selenium contents of copper-bearing sulfide ores and concentrates, and sulfur-selenium ratios, which range from 42,000:1 for copper-poor ore at Løkken-Grong to 1800:1 for copper-rich ore.

Castillo, Antonio del, 1873, Descubrimiento de una nueva especie mineral de bismuto: Naturaleza [Mexico], v. 2, p. 274–276.

Description of a double selenide of bismuth and zinc from Guanajuato, Mexico, is given.

——— 1874, Über eine neue Mineral-Species des Wismuths: Neues Jahrb. Mineralogie, Geologie u. Palaeontologie, Jahrg. 1874, p. 225–229.

A bismuth-zinc-selenium mineral from Guanajuato, Mexico, is described.

Christman, R. A., Heyman, A. M., Dellwig, L. F., and Gott, G. B., 1953, Thorium investigations 1950–52, Wet Mountains, Colorado: U. S. Geol. Survey Circ. 290, p. 7.

Strong, fetid odor in newly broken reddish-stained granitic rocks in the thorium area from Querida to Rosita, Custer and Fremont Counties, Colo., was thought to be caused by selenium compounds, but a chemical analysis showed only traces of selenium. However, volatile compounds may have escaped during grinding of the sample.

Clark, C. W., and Schloen, J. H., 1944, Recovery of precious metals and production of selenium and tellurium at Montreal East: Am. Inst. Mining Metall. Engineers Trans., v. 159, p. 495–520; Tech. Paper 982, 22 p., 1938.

Blister cakes from Hudson Bay Mining and Smelting Company, Flin Flon, Manitoba, and anodes from Noranda Mines, Ltd., Noranda, Quebec, are refined at Montreal East. Both ores have unusually high selenium and tellurium content. Average assay of slimes from Noranda is 22 percent selenium. Selenium recovery plant and process are described.

Clarke, F. W., 1924, The data of geochemistry: U. S. Geol. Survey Bull. 770, p. 19, 186, 273.

Occurrence of selenium in mineral waters and with sulfur as selensulfur in volcanic sublimates of the Lipari Islands is noted.

Clarke, F. W., and Washington, H. S., 1924, The composition of the earth's crust: U. S. Geol. Survey Prof. Paper 127, p. 27, 83, 89, 90, 91–92, 93.

The occurrence of selenium and the association and distribution of selenium minerals are described.

Clennell, J. E., 1906, Assay of bullion containing selenium: Eng. Mining Jour., v. 82, no. 23, p. 1057–1059.

The assay method is described.

——— 1907, Method for analysis of gold-silver bullion: Eng. Mining Jour., v. 83, no. 23, p. 1099–1100.

The method used for determining elements, including selenium, in bullion produced by Mÿjnbouw Maatschappij Redjang Lebong, Sumatra, is described.

Coats, R. R., 1936, Aguilarite from the Comstock Lode, Virginia City, Nevada: Am. Mineralogist, v. 21, p. 532–534.

Silver sulfoselenide occurs in dark-gray sectile masses intimately admixed with other minerals. It appears to be an isomorphous mixture of naumannite and argentite molecules, associated with argentite and silver and replaced by stephanite.

Coleman, R. G., 1956, The occurrence of selenium in sulfides from sedimentary rocks of the western United States [abs.]: Econ. Geology, v. 51, no. 1, p. 112.

Sulfides in the Morrison and Entrada formations of Jurassic age and the Wind River formation of Eocene age contain abnormally large amounts of selenium substituting for sulfur. Sulfides from the same stratigraphic zone usually contain the same relative amounts of selenium regardless of their position with respect to uranium ore deposits. As much as 5 percent selenium was found in pyrite and chalcocite. Sulfides from the Chinle and Shinarump formations of Triassic age usually contain less than 3 ppm selenium except in the Temple Mountain mining district, Utah, where they contain as much as 0.5 percent selenium. Clausthalite and eucairite have been identified from several uranium ore deposits in the Morrison formation. Oxidation of these seleniferous minerals underground or in damp cool places produces a characteristic pink bloom of monoclinic native selenium, which may invert to more stable hexagonal native selenium at higher temperatures on the surface.

Coleman, R. G., and Delevaux, Maryse, 1957, Occurrence of selenium in sulfides from some sedimentary rocks of the western United States: Econ. Geology, v. 52, no. 5, p. 499–527.

Investigations of the minor—and trace-element content of sulfides associated with uranium ore deposits from sandstone-type deposits have shown that selenium commonly substitutes for sulfur. The Morrison formation and Entrada sandstone of Jurassic age and the Wind River formation of Eocene age seem to be seleniferous stratigraphic zones; sulfides deposited within these formations generally contain abnormal amounts of selenium. Tables showing selenium content of sulfides from sedimentary rocks of Triassic, Jurassic, Cretaceous, and Tertiary ages, from many uranium mines in Utah, Colorado, Arizona, New Mexico, and Wyoming, and from some hydrothermal vein deposits are given. The average selenium content of iron sulfides from mineralized rock of Triassic age was 0.0019 percent; of Jurassic age, 0.20 percent; of Cretaceous age, 0.005 percent; of Tertiary age, 0.087 percent. The selenium content of pyrite, marcasite, and chalcocite is much greater than that reported in previously published data. The maximum amount of selenium substituting for sulfur in the pyrite structure was found to be 3 percent by weight. Some copper sulfide samples of Jurassic age which had an extremely high selenium content were shown to contain small inclusions of clausthalite and rarely eucairite. Ferroselite was found in 2 deposits on the Colorado Plateau, and it was established that galena forms an isomorphous series with clausthalite in nature.

During oxidation of the selenium-bearing sulfides and selenides from the Colorado Plateau and Wyoming, the selenium forms pinkish crusts of either monoclinic or hexagonal native selenium intergrown with soluble sulfates, suggesting that under "normal" oxidizing conditions native selenium is more stable than selenites or selenates. The selenium content of sulfides from sedimentary rocks of Mesozoic and Tertiary age is above normal and is related to periods of volcanic and intrusive activity penecontemporaneous with the formation of the containing sediments.

Coleman, W. C., and McCrosky, C. R., 1937, Volumetric determination of selenium—a critical study of the Norris and Fay method: Indus. Eng. Chemistry, Anal. Ed., v. 9, p. 431–432.

Description of simplified procedure for determination of selenious acid by the Norris and Fay method is given.

Collins, W. H., 1937, Timiskaming Sub-province: Geol. Soc. America Bull., v. 48, no. 10, p. 1427–1458.

Sudbury nickel-copper ores contain recoverable amounts of selenium.

Coniglio, L. *See* Zambonini and Coniglio, 1925.

Connor, J. J. *See* Miesch and Connor, 1956.

Cox, T. H. *See* Pugsley and Cox, 1937.

Curl, A. L. *See* also Mathews and others, 1937.

Curl, A. L., and Osborn, R. A., 1938, Report on selenium: Assoc. Official Agr. Chemists Jour., v. 21, no. 2, p. 228–235.

Volumetric determination of selenium using starch indicator is described.

Curran, J. M., 1895, On selenium associated with gold and bismuth, from Mount Hope, N. S. Wales: Royal Soc. New South Wales Jour. and Proc., v. 29, p. 404–406.

Gold occurs at the Mount Allen mine near Mount Hope in an auriferous belt of slate interbedded with Silurian slates. The gold is in plates along laminae of the slate, in grains associated with quartz nodules, and in grains enclosed in aggregates of bismuth oxide and carbonate. Selenium is distributed irregularly throughout the stone. The author believes that selenium and bismuth once existed as a selenide of bismuth which was probably auriferous.

Dake, H. C. *See* DeMent and Dake, 1946.

Damour, A. *See also* DesCloizeaux and Damour, 1881.

——— 1881, Essais chimiques et analyse de la chalcoménite, espèce minérale: Soc. minéralog. France Bull., v. 4, p. 164–167.

Analysis of chalcomenite from Cacheuta, Mendoza, Argentina, is described. The mineral was found in silver, lead, and copper selenide veins, associated with azurite, iron oxide, and lead carbonate.

Dana, E. S., and Wells, H. L., 1890, On some selenium and tellurium minerals from Honduras: Am. Jour. Sci., ser. 3, v. 40, no. 235, p. 78–82.

Specimens from El Plomo mine, Ojojoma district, Department of Tegucigalpa, Honduras, included a blackish gray mineral in quartz-barite gangue found to be an isomorphous mixture intermediate between selenium and tellurium in composition, called selen-tellurium. It most closely resembles native tellurium from Faczebaja which contained 6.7 percent selenium. Also analyzed was a greenish yellow ferric tellurite mineral with selenium replacing part of the tellurium, which was named durdenite.

De la Peña P., R. Luís, 1944, Economic geology, or monograph on the mining region of Huitzuco, State of Guerrero, Mexico: Ingeniería [Mexico], v. 18, p. 205–224.

Livingstonite, stibnite, cinnabar, metacinnabar, barcenite, terlinguaite, guadalcazarite, tiemannite, and onofrite are associated with pyrite, realgar, sulfur, graphite, fluorite, and gypsum in matrices of calcite, gypsum, and dolomite. The sulfides and selenides ascended in hot alkaline solutions and were deposited near the surface by diminution of pressure, temperature, dilution, and oxidation of solutions, and by precipitating agents. (Chem. Abs., v. 39, col. 44.)

Delevaux, Maryse. *See* Coleman and Delevaux, 1957.

Del Rio, Andrea, 1828, Analysis of two new mineral substances, consisting of biseleniuret of zinc and sulphuret of mercury, found at Culebras in Mexico: Philos. Mag., ser. 2, v. 4, p. 113–115.

Two mineral substances, one gray metallic and one red, are both believed to be zinc-mercury selenide minerals.

——— 1836, On riolite, a supposed biseleniuret of zinc: Philos. Mag., ser. 3, v. 8, p. 261–263.

A mineral from Culebras, Mexico, formerly believed to be a biseleniuret of zinc, was found to be native selenium ore with a variable mixture of zinc, mercury, cadmium, and iron.

Delwig, L. F. *See* Christman and others, 1953.

DeMent, Jack, and Dake, H. C., 1946, Rarer metals: Brooklyn, Chemical Pub. Co., p. 251–266.

A summary of the history, mineralogy, occurrence, physical properties, chemical properties, compounds, biological nature, technology, and analysis of selenium.

Derriks, J. J., and Vaes, J. F., 1956, The Shinkolobwe uranium deposit, *in* Proceedings of the international conference on the peaceful uses of atomic energy, v. 6, Geology of uranium and thorium: New York, United Nations, p. 94–128.

Ore from certain massive sulfide veins in the Shinkolobwe mine contains minerals with compositions similar to vaesite and siegenite, except that in one mineral 19 percent of the sulfur is replaced by selenium (selenio-vaesite) and in the other 11 percent of the sulfur is replaced by selenium (selenio-siegenite). In the selenio-sulfide veins, which contain a greater variety of minerals than do the selenium-free sulfide veins, the usual accessory minerals are molybdenite, pyrite, chalcopyrite, bornite, digenite, covellite, and gold. In these veins 3 other selenium minerals are found; one is thought to be related to umangite, and 2 are unidentified but are known to be selenides. A mineral almost identical with molybdenite occurs in certain brecciated formations intimately associated with selenio-sulfides, which is thought to be a variety of selenium molybdenite.

de Salas, Susana M., 1947, Selenium in water. III. Selenium content of some Argentine waters: Rev. obras sanitarias naciön, v. 21, p. 21–24.

No relation between selenium content and the amount of fluorine, vanadium, and arsenic was found in 70 samples of water. The water from 12 purification plants contained 0–5 micrograms per liter selenium. Natural water from 40 different locations contained 0–67 gammas per liter selenium. (Chem. Abs., v. 42, col. 2039.)

Des Cloizeaux, and Damour, A., 1881, Note sur chalcoménite, nouvelle espèce minérale (sélénite de cuivre): Soc. minéralog. France Bull., v. 4, p. 51–55.

Veins containing selenides of lead, silver, and copper are found at Cacheuta, southeast of Mendoza, Argentina. The minerals are identified as cacheutaite, clausthalite, zorgite, berzelianite, and a new copper selenite mineral, chalcomenite.

Dey, A. K. *See* Brown, J. C., and Dey, 1955.

Di Franco, S., 1942, Mt. Etna's mineralogy: Accad. gioenia sci. nat. Catania Atti, v. 5, mem. 9, p. 1–175.

Minerals found in Mt. Etna's eruptive materials include selenium among some 60 sulfide, oxide, carbonate, and silicate minerals. (Chem. Abs., v. 42, col. 491.)

Dimmick, T. D., 1948, Mineral resources of Australia, Minor metals: Australia Bur. Mineral Resources, Geology, and Geophysics Summ. Rept. 35, p. 8–10.

Selenium minerals, uses, prices, and production are discussed. The only commercial source of selenium is anode sludge formed during the electrolytic refining of blister copper. Anode sludge is obtained by Electrolytic Refining and Smelting Company of Port Kembla, New South Wales, and the Mount Lyell Mining and Railway Company at Queenstown, Tasmania. The anode sludges from these companies contain from 1 to 2 percent and 2 percent selenium respectively. Selenium is present in the Mount Morgan ore and one analysis of blister copper from Mount Morgan gave 0.019 percent selenium. The converter flue dust has been found to contain selenium to the extent of 0.04 percent. Selenium is present in small amounts in tellurides at Kalgoorlie and Rothsay, Western Australia, but the occurrences are not of economic importance.

Dios Guevara, Juan de, 1940, The presence of selenium in a sample of Peruvian sulfur: Soc. Quim. Peru Bol., v. 6, no. 1, p. 23–25.

A sample of sulfur from Chachani, Arequipa, contained 99.69 percent sulfur, 0.01 percent selenium, no arsenic, 0.09 percent organic substances, 0.14 percent ash, and 0.07 percent water. (Chem. Abs., v. 34, col. 5603.)

Divers, Edward, and Shimidzu, Tetsukichi, 1883, The red sulphur of Japan: Chem. News, v. 48, p. 284.

Orange-red sulfur similar to the selen-sulfur of the Lipari Islands, Naples, and Hawaii, is found among volcanic sulfur deposits in Japan. It has been obtained from Iwoshima; Motoyama, Satsuma, and Tateyama, Etchui; and Oshima. One specimen examined contained 0.06 percent selenium, 0.17 percent tellurium, 0.01 percent arsenic, and a trace of molybdenum. Yellow sulfur also may contain traces of selenium and tellurium.

Djingheuzian, L. E., 1957, Metallurgical developments in the recovery of some of the less common metals in Canada, *in* Extraction and refining of the rare metals: London, Institution of Mining and Metallurgy, p. 72–90.

Selenium and tellurium occur as copper selenides and copper-gold tellurides in the copper-nickel ores of International Nickel Company of Canada. The amount of selenium in the ore is exceedingly small and no attempt is made to determine the amount. Copper anode slimes contain 8–10 percent selenium. Metallurgy of selenium is described.

Doležal, Jan. *See* Čadek and Doležal, 1957.

Domeyko, J., 1864, Sur quelques nouveaux minéraux du Chile; séléniure double d'argent et de cuivre (eukairite Berz): Annales Mines [Paris], ser. 6, v. 5, p. 458–459.

Specimens of silver-copper selenide mineral (eucairite) were found in Flamenco in the Atacama desert in Chile and in the Province of San Juan, on the other side of the Andes.

——— 1866, Notice sur les séléniures provenant des mines de Cacheuta: Acad. sci. [Paris] Comptes rendus, v. 63, p. 1064–1069.

A vein containing selenium minerals was found in the Province of Mendoza, Argentina, near the area of the coal mines of Cacheuta. The vein is similar to the sulfide ores of Chile, being rich in silver near the surface and becoming rich in lead and poor in silver at depth, except that the ore minerals are selenides rather than sulfides. Near the surface the ore mineral is a polyselenide of silver and copper, with a little iron and cobalt, similar to eucairite, in which there is isomorphous substitution of copper for silver at depth. In the deeper parts of the vein the ore is lead selenide, containing very little silver or copper.

Doty, M. F., 1927, Bibliography on selenium from 1817 to 1925: New York, New York Public Library, 114 p.

A list of references in the New York Public Library on mineralogy, crystallography, properties, uses, and patents of selenium.

Downie, C. C., 1952, Metallurgical fume and flue dusts: Mining Mag. [London], v. 86, no. 2, p. 80–83.

Brief review of methods of recovery of selenium from refinery flue dusts.

Draize, J. H. *See* Beath and others, 1934a, b.

Dudley, H. C. *See* Robinson, W. O., and others, 1934.

Eakle, A. S., 1914, Minerals of California: California State Mining Bur. Bull. 67, p. 47.

Tiemannite occurs in large masses near Clear Lake and in the Abbott mine, Lake County; in the San Joaquin Ranch mine, Orange County; and in the old Guadalupe mine near New Almaden, Santa Clara County.

Earley, J. W., 1949, Studies of natural and artificial selenides; [Pt.] 1— klockmannite: Am. Mineralogist, v. 34, p. 435–440.

Klockmannite from Sierra de Umango, Argentina, was compared with artificial klockmannite and was found to be physically and structurally identical.

——— 1950, Description and synthesis of the selenide minerals: Am. Mineralogist, v. 35, p. 337–364.

A study of natural and artificial selenides, mainly by microscopic and X-ray methods, including naumannite, aguilarite, eucairite, crookesite, berzelianite, umangite, clausthalite, tiemannite, penroseite, guanajuatite, and paraguanajuatite.

Edgington, Glen. *See also* Robinson and Edgington, 1945.

Edgington, Glen, and Byers, H. G., 1942, Selenium content and chemical analyses, pt. 9 *of* Geology and biology of North Atlantic deep-sea cores between Newfoundland and Ireland: U. S. Geol. Survey Prof. Paper 196–F, p. 151–155.

Core samples of sea floor sediments containing volcanic ash were analyzed. Bering Sea core contains 0.25–0.7 ppm selenium; Ocean City, Md., 0.6–2 ppm selenium; North Atlantic, less than 0.1–0.8 ppm. selenium; Caribbean Sea at Bartlett Deep, less than 0.08–0.2 ppm selenium. No evidence of a relation between volcanic activity and selenium accumulation can be drawn from these data.

Edwards, A. B., 1939, Some observations on the mineral composition of Mount Lyell copper ores, Tasmania, and their modes of occurrence: Australasian Inst. Mining and Metallurgy Proc., no 114, p. 61–110.

Selenium occurs as a trace in the Mount Lyell ores, but constitutes 3.9 percent of the final electrolytic slimes from the purification of copper. The amount of selenium in the ore is in the order of 1 part in 124,000. In the North Lyell bornite-chalcopyrite ore body a mineral believed to be berzelianite or eucairite occurs in minute silver-white needle-shaped inclusions in bornite and in chalcocite replacing bornite.

Edwards, A. B., and Carlos, G. C., 1954, The selenium content of some Australian sulphide deposits: Australasian Inst. Mining and Metallurgy Proc., no. 172, p. 31–64.

The possibility of using sulfur-selenium ratios as a method of distinguishing between sulfide deposits of sedimentary or supergene and hydrothermal origin was tested on Australian sulfide ores. Sulfur-selenium ratios of sedimentary pyrites range from 500,000 to 38,000; sulfur-selenium ratios of known hydrothermal pyrites range from 9,000 to 13,000. This investigation shows that high selenium content is associated with hydrothermal origin, but low selenium content is not positive evidence of sedimentary origin, because some hydrothermal sulfides are low in selenium. The amount of selenium in hydrothermal ore depends on the amount of selenium available to mineralizing solutions and on factors controlling the substitution of selenium for sulfur. On the basis of their sulfur to selenium ratios, the deposits at Nairne, South Australia; Broken Hill, N. S. W.; and Mount Isa, Queensland; are considered to be of hydrothermal origin. In many Australian sulfide ores investigated, the early formed minerals, chalcopyrite, pyrite, bornite, and arsenopyrite, are the most seleniferous; later formed minerals, sphalerite, galena, and tetrahedrite, are less seleniferous; and the low-temperature minerals, stibnite, cinnabar, and barite, are poor in selenium. Tables show sulfur and selenium content of sedimentary, supergene, and hydrothermal pyrite, pyrrhotite, chalcopyrite, sulfates, gossans, molybdenite, sphalerite, galena, stannite, stibnite, cinnabar, tetrahedrite, arsenopyrite, and bornite.

Eilers, A., 1913, Notes on the occurrence of some of the rarer metals in blister copper: Am. Inst. Mining Metall. Engineers Bull. 78, p. 999–1000.

The smelter recoveries of selenium from blister copper are: Fairfield, Utah, 2,800 lb. selenium from 5,000 tons blister from Bingham mine; Steptoe, Nev., 3,303 lb. from 3,000 tons blister from Nevada Consolidated mines; Omaha, Neb., 213 lb. from 800 tons blister from Rocky Mountain lead-silver mines; Mountain, Calif., 54 lb. from 150 tons blister; Tacoma, Wash., 336 lb. from 800 tons blister from Pacific coast and Alaska copper ores; Aguascalientes, Mexico, 1,870 lb. from 1,100 tons blister from Mexican gold-silver-copper ores; Cerro de Pasco, Peru, 275 lb. from 2,000 tons blister; Mt. Lyell, Tasmania, 336 lb. from 800 tons blister.

Elkin, E. M. *See also* Schloen and Elkin, 1946, 1950, 1954.

Elkin, E. M., and Margrave, J. L., 1954, Selenium and selenium compounds: Encyclopedia Chem. Technology, v. 12, p. 145–163.

A review of physical and chemical properties, analytical methods, metallurgy, inorganic and organic compounds, health and safety factors, and uses of selenium.

Emmons, W. H., and Laney, F. B., 1926, Geology and ore deposits of the Ducktown mining district, Tennessee: U. S. Geol. Survey Prof. Paper 139, p. 52–53.

Determinations made by the Tennessee Copper Company of selenium in composite samples of Ducktown primary ores taken in December, 1907, give the following selenium contents: Burra Burra mine, 0.0175 percent; London mine, 0.011 percent; Polk County mine, trace. Six samples of lead-bearing copper ores from the secondary zone contained traces of selenium.

Eppson, H. F. *See* Beath and others, 1934b, 1935, 1937a, b, 1939a, b, 1940, 1941; Beath and Eppson, 1947.

Everett, F. D., and Bauerle, L. C., 1957, Investigation of tuffs near Lysite, Wyo., for selenium: U. S. Bur. Mines Rept. Inv. 5296, 30 p.

Exploration work on a seleniferous tuff in the Poison Draw area north of Lysite, Fremont County, Wyo., established that selenium mineralization is erratically distributed in small irregular bodies and is not confined to any one tuff bed. Of 206 samples assayed from 11 drill holes, only 8 contained more than 0.005 percent selenium. The extent and grade of reserves could not be calculated because of the sporadic nature of the mineralization and the lack of correlation between infrequent showings. Metallurgical research to develop a process to recover high-purity selenium from the tuff included water-leaching, precipitation from pregnant solutions, and direct-volatilization methods. Because of the low tenor of ore and the presence of soluble sulfates and bentonitic clay, all methods of extraction were complicated and expensive.

Fernandez, V., 1877, Ueber Guanajuatit-Frenzelit; Schwefelselenwismuthglanz: Zeitschr. Krystallographie u. Mineralogie, v. 1, p. 499.

Guanajuatite and frenzelite from Santa Catarina mine, Guanajuato, Mexico, are the same mineral.

Fisher, Coleman, Jr., 1849, Examination of the telluret of bismuth, from Virginia: Am. Jour. Sci., ser. 2, v. 7, p. 282–283.

Tetradymite from the White Hall mine, Spotsylvania County, was analyzed and found to contain 7.23 percent selenium, 37.96 percent tellurium, and 54.81 percent bismuth.

Fleischer, Michael, 1955, Minor elements in some sulfide minerals: Econ. Geology, Fiftieth Anniversary Volume, pt. 2, p. 970–1024.

Data in the literature on the selenium content of galena, sphalerite and wurtzite, chalcopyrite, pyrite and marcasite, pyrrhotite, and arsenopyrite are summarized in tables for each mineral. The tables list references, type of analysis, and quantitative determinations by arbitrarily selected concentration ranges.

Fleming, G. A. *See also* Walsh and others, 1951.

Fleming, G. A., and Walsh, T., 1957, Selenium occurrence in certain Irish soils and its toxic effects on animals: Royal Irish Acad. Proc., v. 58, sec. B, no. 7, p. 151–166.

Analyses were made of rock, soil, and plant samples from certain parts of Counties Limerick, Tipperary, and Meath where chronic selenium poisoning of animals had been reported. The rocks were Upper and Middle Carboniferous Limestone associated with shale and sandstone beds of the Yoredale and Pendleside series. The source of the selenium was found to be certain shale beds. Soils with the highest selenium content were poorly drained, low-lying, and of high organic matter and molybdenum content. The soils were believed to be of lacustrine origin, the selenium having been carried in by drainage from surrounding areas. As much as 1,200 ppm selenium was found in soils.

Foster, Z. C. *See* Hough and others, 1941.

Franke, K. W., and Painter, E. P., 1937, Effect of sulfur additions on seleniferous soils; Binding of selenium by soil: Indus. Eng. Chemisty, Indus. Ed., v. 29, p. 591–595.

Sulfur in the form of ground sulfur and gypsum was added to a seleniferous field in Gregory County, S. D., on which wheat and corn were grown. The application of sulfur did not inhibit the absorption of selenium by the plants. Plants appear to absorb less selenium during dry seasons than during rainy seasons.

Franke, K. W., Burris, Robert, and Hutton, R. S., 1936, A new colorimetric procedure adapted to selenium determination: Indus. Eng. Chemistry, Anal. Ed., v. 8, p. 435.

A method is described by which colored precipitates of colloidal fineness can be filtered onto a mat of barium sulfate. This procedure can be used for the estimation of 0.005 to 0.15 mg of selenium with an accuracy of 0.001 to 0.01 mg.

Frebold, Georg, 1927a, Beiträge zur Kenntnis der Erzlagerstätten des Harzes, II. Über einige Selenerze und ihre Paragenesen im Harz: Zentralbl. Mineralogie, Jahrg. 1927, Abt. A, no. 1, p. 16–32.

The minerals, clausthalite, tiemannite, naumannite, and umangite, and the mechanical mixtures, lehrbachite (clausthalite and tiemannite), zorgite (clausthalite and umangite), "selenkobaltblei" (clausthalite, "kobaltglanz", hematite), and "seebachite" (clausthalite, umangite, tiemannite), from the Harz are described. The paragenesis of selenium minerals at Clausthal is: pyrite, quartz, calcite, chalcopyrite, clausthalite, tiemannite; at Trogtal: hematite, "kobaltglanz", clausthalite; at Lehrbach: dolomite, clausthalite, tiemannite, umangite, chalcocite, chalcopyrite; at Zorge: quartz, hematite, calcite, clausthalite, tiemannite, umangite; at Tilkerode: pyrite, quartz, dolomite, calcite, chalcopyrite, clausthalite, naumannite, tiemannite.

——— 1927b, Beiträge zur Kenntnis der Erzlagerstätten des Harzes; III Über Berzelianit, Cu_2Se, und ein neues Vorkommen von "Selenkobaltblei" im Harz: Zentralbl. Mineralogie, Jahrg. 1927, Abt. A, no. 6, p. 196–199.

Berzelianite from Skrikerum, Sweden, the Caroline mine near Lehrbach, and the Oberjeremiashöhe mine between Zorge and Wieda is described. Seleniferous material identified as a mixture of clausthalite, "kobaltglanz", and an unknown component from a quarry at Trogtal near Lautenthal is also described. In the Harz, the sulfides, pyrite and chalcopyrite, are older than the selenides, which are the last product of hydrothermal deposition.

Frenzel, August, 1874, Mineralogisches; Selenwismuthglanz: Neues Jahrb. Mineralogie, Geologie u. Palaeontologie, Jahrg. 1874, p. 679–681.

A bismuth-selenium-sulfur mineral from Guanajuato, Mexico, is described.

Friedel, C., and Sarasin, Edmond, 1881a, Forme cristalline du sélénite de cuivre: Soc. minéralog. France Bull., v. 4, p. 225–228.

Artificial chalcomenite has a different crystal form from natural chalcomenite, although the composition is the same.

——— 1881b, Reproduction de la chalcoménite: Soc. minéralog. France Bull., v. 4, p. 176–178.

Artificial selenite of copper was formed from a solution of potassium selenite precipitated by copper sulfate.

Friend, J. N., and Allchin, J. P., 1941, The selenium and tellurium contents of sulfur from Krisuvik, Iceland: Mineralog. Mag., v. 26, p. 9–10.

Analyses of sulfur indicated 12.5 ppm selenium and 250 ppm tellurium in extracted sulfur; 200 ppm selenium and 4000 ppm tellurium in insoluble residue; and 18.9 ppm selenium and 378 ppm tellurium in crude mineral.

Fromme, Joh., 1890, Eucairit aus Argentinien: Jour. prakt. Chemie, v. 150, new ser. v. 42, p. 57–62.

Description and analysis of eucairite from La Rioja Province, Argentina, are given.

Frondel, Clifford. *See* Palache and others, 1944.

Gale, H. S., 1908, Carnotite and associated minerals in western Routt County, Colo.: U. S. Geol. Survey Bull. 340, p. 257–262.

Carnotite deposits at the southern foot of Blue Mountain near Skull Creek, 18 miles east of the Colorado-Utah boundary, occur as crusts and impregnations in sheared and brecciated coarse white sandstone of Jurassic age. The deposits are associated with copper sulfates, vanadates, and carbonates, and contain a copper selenite or selenate mineral. This is the first occurrence of a selenite mineral noted in the United States.

Gavelin, Sven, 1939, Geology and ores of the Malånäs district, Västerbotten, Sweden: Sveriges Geol. Undersökning, Ser. C, no. 424, Årsb. 33, no. 4, p. 124, 134.

Cupriferous pyrite ore of the Eastern Bjurfors ore field contains an average of 0.021 percent selenium. The ore of the Middle Bjurfors field contains 0.002 and 0.012 percent selenium.

——— 1954, A telluride assemblage in the Rudtjebäcken pyrite ore, Västerbotten, N. Sweden: Sveriges Geol. Undersökning, Ser. C, no. 536, Årsb. 48, no. 1, 13 p.

Tellurides of lead, silver, and gold are found in pegmatite associated with a compact pyrite-sphalerite-chalcopyrite ore in the Rudtjebäcken mine, Skellefte district, North Sweden. The telluride-bearing pegmatite contains 0.07 percent tellurium and 0.013 percent selenium.

——— 1955, Sulphide mineralization in the Skellefte district, northern Sweden, and its relation to regional granitization: Econ. Geology, v. 50, no. 8, p. 814–831.

Minerals of which selenium forms an essential constituent have been identified from only a few deposits in the Skellefte district. Ödman described 2 sulphominerals at Boliden which, because of their significant content of selenium, were called selenocosalite and selenokobellite. In the principal sulfides of the ores highly varying values for selenium are obtained from different samples of the same mineral from the same deposit. In pure sulfide minerals values from less than 0.001 to 0.14 percent selenium were obtained. The succession galena-chalcopyrite-sphalerite-pyrite indicates a decreasing selenium content.

Geilmann, Wilhelm, and Biltz, Wilhelm, 1931, Über die Zusammensetzung vulkanischen Schwefels vom Papandajan (West-Java): Zeitschr. anorg. allg. Chemie, v. 197, p. 422–428.

Two kinds of sulfur are found at Papandajan: (a) yellow pure sulfur which coats the ground around active volcanic craters and contains bright red and orange spots; (b) gray less pure sulfur which occurs around sulfur swamps and contains a metallic material like pyrite. The yellow sulfur contains more selenium than the gray, as well as arsenic, lithium, and thallium.

Geilmann, Wilhelm, and Rose, Herm., 1928, Ein neues Selenerzvorkommen bei St. Andreasberg im Harz: Neues Jahrb. Mineralogie, Geologie u. Palaeontologie Beil.-Band, Abt. A, v. 57, pt. 2, p. 785–816.

Selenium deposits in the "Roter Bär" mine, east of St. Andreasberg, Harz, are described and are compared with other selenium ores in the Harz. The minerals clausthalite, tiemannite, guanajuatite, zinc selenide, naumannite, umangite, and berzelianite are described and their chemical and physical properties are described.

Genth, F. A., 1855, Contributions to mineralogy; [Pt.] 5—Tetradymite: Am. Jour. Sci., ser. 2, v. 19, p. 15–16.

Two samples of tetradymite were examined. The first was associated with gold and quartz and was believed to come from the White Hall mine, Spotsylvania County, Va. The second sample was broad folia of tetradymite implanted in decomposed micaceous slate from the Tellurium mine, Fluvanna County, Va. Only traces of selenium were found in both samples.

——— 1885, Contributions to mineralogy: Am. Philos. Soc. Proc., v. 23, no. 121, p. 30–35.

Joseite from San Jose, Minas Geraes, Brazil, was found to contain a small amount of selenium. Seleniferous galenobismutite from Falun, Sweden, is described and analyses are given.

——— 1891, Contributions to mineralogy, no. 51: Am. Jour. Sci., ser. 3, v. 41, p. 401–403.

Descriptions and analyses are given of: aguilarite from the San Carlos mine, Guanajuato, Mexico; seleniferous bismuthinite probably from Guanajuato, Mexico; and guanajuatite (frenzelite) from Germany.

——— 1892, Contributions to mineralogy, no. 54: Am. Jour. Sci., ser. 3, v. 44, p. 381–383.

Descriptions and analyses of aguilarite are given.

Gibson, F. H., and Selvig, W. A., 1944, Rare and uncommon chemical elements in coal: U. S. Bur. Mines Tech. Paper 669, 23 p.

Selenium acts very much like arsenic in some qualitative tests. Selenium has been noted in coal from Liége, Belgium, and in coke from England.

Gilbert, C. S. *See* Beath and others, 1934a, b, 1935, 1937a, b, 1939a, b, 1940, 1941, 1946; Beath and Gilbert, 1936.

Gile, P. L. *See* Hough and others, 1941.

Giustiniani, E. *See* Matteucci and Giustiniani, 1897.

Gmelin's Handbuch der anorganischen Chemie, 1942, Selen: 8th ed., Berlin, Verlag Chemie, System-Nr. 10, teil A, lief. 1, p. 1–75.

History, uses, compounds, and natural occurrence of selenium are discussed.

Goldschmidt, V. M., 1937, The principles of distribution of chemical elements in minerals and rocks: Chem. Soc. London Jour., 1937, pt. 1, p. 655–673.

One percent of the selenium supplied to sea water is present. The amount of selenium which has potentially been supplied to sea water is so great that a serious poisoning of the ocean would have been caused if some phenomena of elimination had not been in action. Selenium has been removed from aqueous solutions by adsorption on freshly precipitated hydroxides of iron. Considerable concentrations of selenium are in sedimentary iron ores.

Goldschmidt, V. M., 1954, Geochemistry: Oxford, Clarendon Press, p. 532–540.

The average abundance of selenium in magmatic rocks is 0.09 ppm; in meteorites, 7 ppm. Pneumatolytic and high-temperature hydrothermal sulfide ores contain more selenium than medium- and low-temperature sulfide ores. Selenium also is markedly associated with gold and silver deposits of the epithermal range. In the cycle of weathering, very little selenium remains in sea water; most is removed with the hydrolyzate sediments, mainly with organic matter, iron and manganese hydroxides, and iron sulfides. Two parts per million selenium was noted in pyritic lead veins of Gilpin County, Colo.; selenium also noted in ores from Mansfeld, Rammelsburg, Bad Grund, and Upper Silesia, Germany, and from St. Agnes, Cornwall, England.

Goldschmidt, V. M., and Hefter, O., 1933, Zur Geochemie des Selens: Gesell. Wiss. Göttingen Nachr., math.-phys. Kl., v. 3, no. 35; v. 4, no. 36, p. 245–252.

The similarity of sulfur and selenium suggests that they may be geologically isomorphous, as they are in certain sulfide minerals. Sulfur of volcanic origin contains perceptible amounts of selenium, but in sedimentary rock formations the sulfur is substantially free from selenium. A study of anhydrite, polyhalite, kainite, and kieserite from sea-water deposits shows that in these sulfates the selenium, in proportion to the sulfur, is 10 to 100 times rarer than in eruptive rocks. The higher oxidation potential required for selenium explains the conversion of sulfur to sulfate ion whereas the selenium remains as selenide or native selenium independent of the fate of sulfur. The selenium is therefore removed from the circulating solutions by the reducing action of rocks and minerals and may be expected to accumulate in coal deposits, a conclusion verified by the occurrence of selenium in Yorkshire anthracite. (Chem. Abs., v. 27, p. 4757.)

Goldschmidt, V. M., and Strock, L. W., 1935, Zur Geochemie des Selens, II: Gesell. Wiss. Göttingen Nachr., math.-phys. Kl., v. 4, new ser., v. 1, no. 11, p. 123–142.

The selenium content of primary magmatic sulfides was found to be higher than that of other materials, but the selenium-sulfur ratio was highest in sedimentary iron and manganese oxide ores. Sea water, salt beds, and sedimentary rocks are low in selenium. This is because selenium reaching the ocean is not oxidized to selenate, but is absorbed by precipitating iron and manganese hydroxides. The only salt deposit high in selenium is Chilean caliche, formed under oxidizing conditions sufficiently high to convert selenium to selenate. (Chem. Abs., v. 30, col. 1334.)

Goni, J., and Guillemin, C., 1953, Données nouvelles sur les sélénites et séléniates naturels: Soc. française minéralogie et crystallographie Bull., v. 76, p. 422–429.

A brief history of the discovery of natural selenite minerals and descriptions of the occurrence and mineralogy of lead selenate from Pacajake, Bolivia, and Cacheuta, Argentina; molybdomenite from Cacheuta, Argentina, and Trogtal, Lautertal, Hartz, Germany; and ahlfeldite, an alteration product of penroseite, from Pacajake, Bolivia. The authors consider the existence of cobaltomenite doubtful. The paragenesis of the secondary minerals in limonite at Pacajake is anglesite, cerussite, selenate of lead, chalcomenite, and ahlfeldite.

González Reyna, Jenaro, 1956, Riqueza minera y yacimientos minerales de México: rd ed., Internat. Geol. Cong., 20th, Mexico 1956, Banco de México, S. A., Dept. Inv. Indus., p. 301.

No commercially exploitable deposits of selenium minerals exist in Mexico. Selenium occurs associated with silver minerals or forming part of their composition in silver ores associated genetically with andesitic rocks, and is recovered as a byproduct of silver refining. All recent selenium production has been from the State of Guanajuato.

Gordon, S. G., 1925, Penroseite and trudellite: two new minerals: Acad. Nat. Sci. Philadelphia Proc., v. 77, p. 317–321.

A mineral believed to come from the Colquechaca silver mines, Bolivia, was identified as penroseite, a lead-copper selenide with minor amounts of nickel and cobalt. The mineral contained thin veins of goethite or limonite and a white selenide, believed to be clausthalite, and was found in fissure veins in rhyolite.

Gott, G. B. *See* Christman and others, 1953.

Grasselly, Julius, 1948, Analyses of some bismuth minerals: Univ. Szeged, Acta Mineralog. Petrog., Sec. Sci. Nat., v. 2, p. 24–30.

Analyses of joseite, grünlingite, and cosalite from Rézbánya-Baita, all of which contain small amounts of selenium.

Greaves, J. E. *See* Holt and Greaves, 1941.

Grip, Erland, and Ödman, O. H., 1942, The telluride-bearing andalusite-sericite rocks of Mångfallberget at Boliden, northern Sweden: Sveriges Geol. Undersökning, Ser. C, no. 447, Årsb. 36, no. 4, 21 p.

Tellurobismuthite at Mångfallberget contains small quantities of selenium substituting for tellurium. Selenium is much rarer here than at Boliden mine.

Grutt, E. W., Jr., 1956, Uranium deposits in Tertiary sedimentary rocks in Wyoming and northern Colorado, *in* Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 361–370.

At the Lucky Mc mine, Gas Hills anticline, Fremont County, Wyoming, in the upper Wind River formation, native selenium has been identified in minute particles, and an unknown selenite or selenate mineral occurs in reddish streaks.

Guillemin, C. *See* Goni and Guillemin, 1953.

Hagner, A. F. *See* Beath and others, 1946.

Halen, S., 1921, Neue Forschungen betreffend das Selen and seine Verbindungen: Edel-Erden u. -Erze, v. 2, p. 105–107.

Bibliography on the sources, extraction, compounds, and uses of selenium.

Hance, F. E., 1939, Report on chemistry: Hawaiian Sugar Planters' Assoc. Proc., Rept. Comm. in Charge Expt. Sta., v. 59, p. 88–100.

Selenium in excess of 10 ppm was not found in Hawaiian agricultural and grazing soils. With the exception of Ekoa, (*Leucaena glauca*), which possesses the property of accumulating selenium, no samples of Hawaiian vegetation contained more than traces of selenium. A sample of the coral-red exudate from Mauna Loa volcano contained 6000 ppm selenium. (Chem. Abs., v. 34, col. 6005.)

Harand, Josef. *See* Alber and Harand, 1939.

Harloff, C. S., and Johnson, H. F., 1933, The Nichols Series system of electrolytic copper refining: Am. Inst. Mining Metall. Engineers Trans., v. 106, p. 403.

Typical analyses of blister copper treated at Nichols Copper Co. refinery at Laurel Hill, N. Y., showed the following percentages of selenium-tellurium content: Katanga, 0.0002; Rio Tinto, 0.0065; Pyrite, 0.002; Magma, 0.0135; U. V. X., 0.15; Granby, 0.025; Phelps Dodge, 0.03; Tennessee, 0.025; Ducktown, 0.016; Bor, 0.0007; Noranda, 0.20; Nichols blister, 0.02.

Harris, W. E. *See* Walker and others, 1941.

Hawkes, H. E., 1957, Principles of geochemical prospecting: U. S. Geol. Survey Bull. 1000–F, p. 228, 229, 291, 299.

The abundance of selenium in igneous rocks is 0.09 ppm; its average abundance in fresh water is 8 ppm, and in the mineral residue of fresh water, 55 ppm. The role of selenium in vegetation and the use of indicator plants in prospecting are described briefly.

Headden, W. P., 1907, Some mattes formed in melting zinc-box precipitates—their composition and what it suggests: Colorado Sci. Soc. Proc., v. 8, p. 349–362.

Two analyses of matte from the Camp Bird mine, Ouray, Colo., representing 10 months milling in 1906–07, contained 0.99 percent and 1.500 percent selenium. Selenium in the Camp Bird ore does not occur in pyrites, as is commonly thought, for the pyrites contain only traces of selenium, but is believed to occur in some other mineral which passes into the slimes. No selenium minerals were noted in the Camp Bird ore. Mattes from Cripple Creek contained no selenium.

Hefter, O. *See* Goldschmidt and Hefter, 1933.

Heier, Knut, 1953, Clausthalite and selenium-bearing galena in Norway: Norsk geol. tidsskr., v. 32, p. 228–231.

Minerals of the isomorphous series clausthalite-galena from Kongsberg silver mines and from Numedal contained 80, 79, and 93 mol. percent of lead selenide. Selenium-bearing galena containing about 10 molecular percent of lead selenide was found also at Åsland and Åslandåsen, North Vinoren, north of Kongsberg.

Heikes, V. C. *See* Butler and others, 1920.

Hernandez Ortiz, David. *See* McAllister and Hernandez Ortiz, 1945.

Hershey, A. L., 1945, Some poisonous plant problems of New Mexico: New Mexico Agr. Expt. Sta. Bull. 322, 23 p.

In New Mexico selenium indicator plants are generally found on Cretaceous soils and alluvial formations. Selenium indicator plants and the area of their occurrence in New Mexico are listed. The report contains maps showing the occurrence of formations of Cretaceous age in New Mexico and locations where plants have been collected which contained more than 10 ppm selenium, and areas where common indicator plants of selenium have been collected.

Herzenberg, Robert, and Ahlfeld, Friedrich, 1935, Blockit, ein neues Selenerz aus Bolivien: Zentralbl. Mineralogie, Jahrg. 1935, Abt. A, no. 9, p. 277–279.

Blockite (penroseite) was found at the Hiaco silver mine, Pacajake, 30 km northeast of Colquechaca, Bolivia. The mineral was in a siderite vein in quartzite, associated with pyrite, chalcopyrite, naumannite, and barite. Ahlfeldite, a nickel selenite mineral, occurs as an alteration product of blockite. Blockite, a nickel-copper selenide, with lead and cobalt, and 0.022 percent of platinum metals, was believed by the authors to be a different mineral from penroseite.

Hess, F. L., 1909, Selenium: U. S. Geol. Survey Mineral Resources U. S., 1908, pt. 1, p. 715–717.

Brief review of selenium occurrences and uses.

——— 1913, Antimony, bismuth, and selenium in 1912: U. S. Geol. Survey Mineral Resources U. S., 1912, pt. 1, p. 1045.

Selenium production in 1912 was from anode slimes left in the electrolytic refining of copper.

——— 1914, The production of antimony, arsenic, bismuth, selenium, and tellurium in 1913: U. S. Geol. Survey Mineral Resources U. S., 1913, pt. 1, p. 289.

Selenium occurrence in uranium-vanadium-bearing sandstones is mentioned.

——— 1916, Selenium: U. S. Geol. Survey Mineral Resources U. S., 1914, pt. 1, p. 969–974.

Selenium minerals and their occurrences are described. Selenium recovery from blister copper in the United States and foreign countries is discussed, with particular emphasis on the selenium content of blister copper from Butte, Mont., treated at the Anaconda and Great Falls smelters. Potential sources, uses, and field tests are given.

——— 1917, Field tests for selenium: U. S. Geol. Survey Mineral Resources U. S., 1915, pt. 1, Metals, p. 849.

When heated on charcoal or in a closed tube, selenium gives off a fetid odor like "rotten horseradish", and forms a red coating and a silvery-white coating of selenium dioxide.

——— 1925, New and known minerals from the Utah–Colorado carnotite region: U. S. Geol. Survey Bull. 750–A, p. 63–78.

Traces of selenium were noted in analyses of black vanadium-bearing sandstone from Jo Dandy mine, Paradox Valley, Montrose County, Colo., and in rauvite and metatorbernite from Temple Mountain, Utah.

Hess, F. L., 1933, Uranium, vanadium, radium, gold, silver, and molybdenum sedimentary deposits, *in* Ore deposits of the western United States: New York, Am. Inst. Mining Metall. Engineers, chap. 10, pt. 2, p. 450–481.

Discusses selenium in silver ore at the Silver Reef mine near Leeds, Utah, and in asphaltites in Shinarump conglomerate, and the origin of seleniferous uranium-vanadium deposits on the Colorado Plateau. At Silver Reef, the silver occurs as chloride and sulfide above water level, mostly associated with plant remains and carbonaceous matter in Painted Desert sandstone. Silver was originally deposited as silver sulfide and selenide, and reprecipitated above the water table as cerargyrite and selenide. Copper, uranium, and vanadium are associated with the silver ore.

Heusler, F., and Klinger, H., 1885, Ueber Selenide aus den Anden: Deutsche chem. Gesell. Ber., v. 18, p. 2556–2561.

Gives the compositions of lead-copper selenide minerals from the Andes.

Hewett, D. F., Callaghan, Eugene, Moore, B. N., Nolan, T. B., Rubey, W. W., and Schaller, W. T., 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Survey Bull. 871, p. 28.

Selenium was reported in relative abundance in pyritic ores of the United Verde mine, Jerome district, Yavapai County, Ariz.

Hey, M. H. *See* Bannister and Hey, 1937.

Heyman, A. M. *See* Christman and others, 1953.

Hill, J. M., 1915, Some mining districts in northeastern California and northwestern Nevada: U. S. Geol. Survey Bull. 594, p. 24, 148–149.

Gold-bearing veins in the High Grade, Winters, and Hayden Hill districts, Calif., and the Aurora and Silver Star districts, Nev., belong to one class of late Tertiary mineral deposits and are characterized by white quartz, adularia, and calcite veins with numerous offshoots into highly altered country rock carrying finely distributed free gold, tetrahedrite, pyrite, chalcopyrite, and frequently selenium in an unknown compound. In the Aurora district the veins are fine-grained quartz banded by dark streaks of quartz, adularia, argentiferous tetrahedrite, pyrite, chalcopyrite, free gold, and a soft bluish-gray mineral supposed to be a combination of gold and possibly silver with selenium. The similarity between these veins and the quartz-adularia veins carrying gold and selenium at Tonopah, Nev., and Republic, Wash., is discussed.

Hill, W. L. *See* Rader and Hill, 1935.

Hillebrand, W. F., 1905, Tellurium minerals from Colorado: U. S. Geol. Survey Bull. 262, p. 57.

Specimens of tetradymite from a locality near Whitehorn, Fremont County, Colo., contained approximately 0.20 percent selenium.

Hillebrand, W. F., Merwin, H. E., and Wright, F. E., 1914, Hewettite, metahewettite, and pascoite, hydrous calcium vanadates: Am. Philos. Soc. Proc., v. 53, no. 213, p. 31–54.

Two selenium minerals accompany metahewettite from the Thompsons district, Utah, and have been noticed at Paradox Valley and Henry Mountains, Utah: (a) Gray hydrous silicate of aluminum, vanadium, and potassium contains inclusions identified as selenium and bituminous matter; (b) A selenium mineral occurs in amounts up to one percent included as specks in gray silicate. The selenium is probably present as elemental selenium and not as a selenide or oxygenated compound.

Hillebrand, W. F., Lundell, G. E. F., Bright, M. S., and Hoffman, J. I., 1953, Applied inorganic analysis: 2d ed., New York, Wiley, p. 327–338.

Chemistry of selenium, attack of selenium minerals, and methods of separation and determination of selenium are described.

Hilmoe, R. J. *See* Searight and others, 1946.

Hoffman, J. I. *See* Hillebrand and others, 1953.

Holmes, R. S. *See* Slater and others, 1937.

Holt, W. L., and Greaves, J. E., 1941, The occurrence of selenium in Utah forage plants: Soil Sci., v. 51, no. 4, p. 299–306.

Small non-toxic amounts of selenium are present in most forage plants in the Trout Creek area and in the Pine Valley and Antelope Valley area; plants in the Cache National Forest Reserve area are almost free of selenium. No apparent relationship was observed between the selenium and sulfur content of forage plants.

Holtz, H. C. *See* Howe and Holtz, 1919.

Hopkinson, F. J. *See* Wernimont and Hopkinson, 1940.

Horn, M. J., 1934, Qualitative method for selenium in organic compounds: Indus. Eng. Chemistry, Anal. Ed., v. 6, p. 34–35.

Describes method of testing for selenium requiring very small amounts of material.

Hough, G. J., Gile, P. L., and Foster, Z. C., 1941, Rock weathering and soil profile development in the Hawaiian Islands: U. S. Dept. Agriculture Tech. Bull. 752, 43 p.

Exceedingly young soil profiles contained no selenium. Young soil profiles derived from volcanic ash contained from 0.1 to 0.4 ppm selenium in areas of light rainfall and from 1.5 to 6 ppm selenium in areas of heavy rainfall. Old soil profiles derived from middle aged lava contained 0.4 to 4 ppm selenium in areas of light rainfall and 12 to 14 ppm selenium in areas of heavy rainfall. These are among the highest concentrations of selenium encountered in soils that do not produce seleniferous vegetation. It is presumed that selenium is present in these soils as an insoluble ferric selenite.

Howe, J. L., and Holtz, H. C., 1919, Bibliography of the metals of the platinum group, platinum, palladium, iridium, rhodium, osmium, ruthenium, 1748–1917: U. S. Geol. Survey Bull. 694, 558 p.

Contains references on selenium compounds with platinum and the influence of selenium on platinum.

Hukki, R. T., and Runolinna, U., 1950, Separation of precious metals from anode slimes by flotation: Am. Inst. Mining Metall. Engineers Trans., v. 187, p. 1131–1132.

Investigation at Outokumpu, Finland, of methods of separation of gold and silver, believed to be in the form of selenides, by flotation from anode slimes.

Huntting, M. T., 1956, Inventory of Washington minerals, part II, Metallic minerals: Washington Div. Mines and Geology Bull. 37, v. 1, p. 282–283; v. 2 (map), p. 46–47.

The properties, uses, production, prices, ore minerals, and geology and occurrences of selenium are described. Selenium occurs in the Blaine Republic, Flag Hill, Golden Valley, Lamefoot, Republic, and Valley mines, Republic district, Ferry County. Mine locations are shown on a map.

Hurd-Karrer, A. M., 1934, Selenium injury to wheat plants and its inhibition by sulfur: Jour. Agr. Research, v. 49, no. 4, p. 343–357.

Selenium injury to plants can be inhibited by the addition of sulfur, either as sulfate or as elemental sulfur. The amount of sulfur required varies with the toxicity of the soil.

——— 1935a, Factors affecting the absorption of selenium from soils by plants: Jour. Agr. Research, v. 50, no. 5, p. 413–427.

Factors affecting selenium absorption are available sulfur, soil type, amount of sand in the soil, method of adding selenium, form of selenium in soil, and growth of previous crops.

——— 1935b, Selenium absorption by plants and their resulting toxicity to animals: Smithsonian Inst. Ann. Rept., 1935, p. 289–301.

Addition of sulfur as sulfate to seleniferous soils retards absorption of selenium by plants. Because of their chemical similarity, sulfur and selenium may be able to play interchangeable roles in plant chemistry.

Hutton, R. S. *See* Franke and others, 1936.

Imperial Institute, 1937, The sources, production and uses of selenium and tellurium: Imp. Inst. [London] Bull., v. 35, no. 1, p. 56–67.

Properties, uses, and production of selenium, including methods of extraction from pyrites and copper refinery slimes.

Industrial and Engineering Chemistry, 1916, Seleniferous pyrites in the manufacture of sulfite cellulose: Indus. Eng. Chemistry, Indus. Ed., v. 8, p. 278–279.

Some selenium is contained in all pyrites; the ratio between sulfur and selenium in pyrites varies from 10,000:1 to 100,000:1. A method for quantitative determination of selenium in pyrite is described.

Iron Age, 1952, Selenium: Iron Age, v. 170, no. 14, p. 283–284.

Summary of uses, availability, and sources of selenium.

Ishibashi, Masayoshi, 1953, Minute elements in sea-water: Oceanog. Works Japan Rec., new ser., v. 1, no. 1, p. 88–92.

Marine waters collected at Shirahama, Wakayama Prefecture, Japan, contained 4–6 micrograms per liter of selenium. (Chem Abs., v. 48, col. 6175.)

Ishibashi, Masayoshi, Shigematsu, Tsunenobu, and Nakagawa, Yasuharu, 1953, Determination of selenium in sea water: Oceanog. Works Japan Rec., new ser., v. 1, no. 2, p. 44–48.

Selenium content of Japanese coastal waters ranged from 4 to 6 micrograms per liter. (Chem. Abs., v. 49, col. 2250.)

Jacks, G. V., and Scherbatoff, H., 1940, The minor elements of the soil: Imp. Bur. Soil Sci. [Harpenden] Tech. Commun. 39, p. 73–81.

Compilation of data on selenium in soils, including the form of selenium in soil, sulfur-selenium relationships of soils, and relationship of plants to content and form of selenium in soils.

Janes, T. H., 1956, Rare, or less common, metals in Canada: Canada Dept. Mines and Tech. Surveys Mineral Resources Inf. Circ., M. R. 21, p. 9.

Selenium is recovered in Canada by Canadian Copper Refiners Ltd., Montreal East, from copper anodes produced at Noranda and Gaspe smelters of Noranda Mines Ltd. and from blister copper produced at Hudson Bay Mining and Smelting Company at Flin Flon. It is also recovered at Copper Cliff refinery of International Nickel Co. of Canada Ltd. as a black, free-flowing, amorphous powder averaging 99.5 percent selenium.

Japan Geological Survey, 1956, Geology and mineral resources of Japan: p. 182.

Selenium is produced mostly as a byproduct from electrolytic copper refineries, and partly from sulfuric acid factories. In 1953, selenium was produced from 10 refineries including Niihama, Saganoseki, Hitachi, Nikko, and from the Miike sulfuric acid factory. Selenium is contained in minerals such as sulfur, pyrite, chalcopyrite, and other sulfide minerals.

Jenney, W. P., 1913, The chemistry of ore deposition, *in* Emmons, S. F., Ore deposits: New York, Am. Inst. Mining Metall. Engineers, p. 325–326.

A discussion of the association of selenium with silver ores at Silver Reef, Utah, and the origin and enrichment of the ores. Selenium usually occurs with minerals believed to have been formed by highly heated vapors and solutions in direct association with igneous disturbances. Its presence at Silver Reef seems to favor the theory of the deposition of silver through fissures. The silver was deposited originally in the sandstone in combination with selenium and probably sulfur by the reducing action of lignitic matter. The ore bodies were later enriched by secondary precipitation of silver sulfides.

Jensen, C. L., *See* Peterson and others, 1957.

Jimbo, Kotora, 1899, Notes on the minerals of Japan: Tokyo Imp. Univ., Coll. Sci. Jour., v. 11, p. 215.

Selenium-sulfur occurs at Tateyama-Jigoku, Province of Etchu, and on the Island of Iwojima near the Province of Osumi.

Johansson, K., 1924, Ett par selenförande mineral från Falu gruva: Arkiv kemi, v. 9, no. 9, 23 p.

Describes wittite and seleniferous chiviatite found at Falun with quartz and magnetite in amphibole rock.

Johnson, H. F. *See* Harloff and Johnson, 1933.

Johnson, L. R. *See* Thorvaldson and Johnson, 1940.

Jorisson, A., 1896, Sur la présence du molybdène, du selenium, du bismuth, etc., dans le terrain houiller du pays de Liége: Soc. géol. Belgique Annales, v. 23, p. 101–105.

Flue dusts recovered from furnaces burning coal from the Sainte-Marguerite mine and from Beyne, Liege, were analyzed and found to contain selenium.

Jornlin, D. F. *See* Olson and others, 1942a.

Kaiser, E. P., 1954, Selenium in sulfide ores: Geol. Soc. America Bull., v. 65, p. 1379.

More than 50 samples of sulfide ores and their products were analyzed for selenium. Mill concentrates relatively high in selenium are also high in bismuth, cobalt, tin, and zirconium. Minerals containing selenium are almost never recognized in the deposits. Selenium is relatively more abundant in sulfide deposits of certain areas, one of which is the mountainous region of central Arizona. There is no apparent connection between the concentration of selenium in epigenetic ore deposits and its concentration in sedimentary rocks such as the selenium-bearing shales of Cretaceous age in the Great Plains area. These selenium-bearing shales are widespread and probably received their selenium from Cretaceous volcanic materials. Some recent volcanic materials, especially sulfur, are notably rich in selenium.

Keller, Edward, 1914, American progress in the assay of copper bullion: Am. Inst. Mining Metall. Engineers Trans., v. 46, p. 764–788.

Mentions selenium impurities and how they form. Copper bullion that presumably came from Butte, Montana, carries 0.0072 percent selenium and tellurium.

Keys, W. S., and White, R. L., 1956, Investigation of the Temple Mountain collapse and associated features, San Rafael Swell, Emery County, Utah, *in* Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 285–298.

Selenium is particularly abundant in asphaltic ores in the Moss Back member of the Chinle formation in the Temple Mountain mineral belt. An average uranium to selenium ratio of 950:1 was reported from the Campbird No. 7 ore.

Klason, P., and Mellquist, H., 1912a, Determination of selenium in pyrite: Papier-Zeitung, v. 37, p. 767–768.

The selenium content of pyrites from various sources was determined by the iodometric method. Total selenium varied from 4.01 grams per ton in certain Norwegian ores to 90 grams per ton in Falun ore. Pyrites high in copper and lead contain less selenium than pyrites free of these metals. This is also true of sulfur. Louisiana sulfur is mentioned as almost pure, but the selenium content is not given. (Chem. Abs., v. 6, col. 1660.)

——— 1912b, Iodometric methods for the quantitative determination of small amounts of selenium in sulfur and pyrites: Zeitschr. angew. Chemie, v. 25, p. 514–518; Papier-Zeitung, v. 37, p. 374–376, 411–412.

Sulfur from Japan and Sicily tested by iodometric methods contained from 1 to 20 grams per ton selenium. (Chem. Abs., v. 6, col. 1578.)

Klein, A. K., 1941, Report on selenium: Assoc. Official Agr. Chemists Jour., v. 24, no. 2, p. 363–389.

Methods for determining selenium are described.

——— 1942, Report on selenium: Assoc. Official Agr. Chemists Jour., v. 25, no. 2, p. 403–410.

Methods for determining selenium are described.

——— 1943, Report on selenium: Assoc. Official Agr. Chemists Jour., v. 26, no. 2, p. 346–352.

Methods of determining selenium are described.

Kleinhampl, F. J. *See* Cannon and Kleinhampl, 1956.

Klinger, H. *See* Heusler and Klinger, 1885.

Klockmann, F., 1891, Mineralogische Mittheilungen aus der Sammlungen der Bergakademie zu Clausthal: Zeitschr. Krystallographie u. Mineralogie, v. 19, p. 265–275.

Describes eucairite and umangite from Argentina.

Knight, H. G. *See* also Byers and Knight, 1935.

Knight, H. G., 1935, The selenium problem: Assoc. Official Agr. Chemists Jour., v. 18, no. 1, p. 103–108.

Review of research on seleniferous soils and selenium poisoning.

Knight, S. H., 1937, The occurrence of selenium and seleniferous vegetation in Wyoming; Pt. 1—The rocks and soils of Wyoming and their relations to the selenium problem: Wyoming Agr. Expt. Sta. Bull. 221, p. 3–27.

Selenium occurs in the following formations in Wyoming: Little Medicine tongue of the Dinwoody (basal Chugwater) and the Phosphoria formations of Permian age; Morrison formation of Jurassic age; Pierre, Steele, Niobrara, Lower Cloverly, Mesaverde, Cody, Hilliard, and Upper Cloverly formations of Cretaceous age; and the Wind River, Chadron, Bridger, Uinta, Fort Union, and Ferris formations of Cenozoic age.

Koch, Sandor, 1948, Bismuth minerals in the Carpathian basin; Univ. Szeged. Acta Mineralog. Petrog., Sec. Sci. Nat., v. 2, p. 1–23.

Tetradymite containing small amounts of selenium occurs in all mineral localities of the Carpathian basin. Cosalite from Rézbánya contains 6.57 percent selenium. Csiklovaite, similar to tetradymite, is described.

Koeppel, W. E., and Schellinger, A. K., 1957, Extraction of some less common metals from smelter and refinery intermediates at La Oroya, Peru, *in* Extraction and refining of the rare metals: London, Institution of Mining and Metallurgy, p. 96–103.

Article contains a brief review of physical and chemical properties and the recovery of selenium from copper smelter products. Blister copper at La Oroya contains 0.03 percent selenium and copper anode slimes contain 1.8–2 percent selenium.

Komkov, A. I. *See* Buryanova and Komkov, 1955; Buryanova and others, 1957.

Kovalev, G. A. *See* Buryanova and others, 1957.

Krauskopf, K. B., 1955, Sedimentary deposits of rare metals: Econ. Geology, Fiftieth Anniversary Volume, pt. I, p. 411–463.

Most minor metals are more concentrated in shale than in sandstone or limestone, and for most elements, the amounts in shale are close to the crustal abundance. The abundance of selenium in sedimentary rocks is high, possibly because it is supplied to the sediments by volcanic emanations as well as by erosion. The abundance of selenium in the earth's crust is 0.09 ppm; its average concentration in shale is 0.5 to 1 ppm; in sandstone, 1 ppm; in limestone, 0.1 to 1 ppm; in iron oxide sediments, 0.5 to 5 ppm. Iron oxide forms a positive colloid, and anion-forming elements such as selenium tend to concentrate with it. The concentration of selenium in evaporites is far below the crustal average. Selenium is enriched by a factor of 300 in sedimentary pyrites. Selenium is widely disseminated and concentrated in clastic sedimentary rocks in the Rocky Mountain region, where its presence is attributed to volcanic activity and leaching of the selenium chiefly as soluble selenate. It is also present in sandstones of the Colorado Plateau and is said to show a rough correlation with vanadium.

Krilanovich, N. J., *See* McCullough and others, 1946.

Krusch, P. *See* Beyschlag and others, 1914.

Lakin, H. W. *See also* Byers and others, 1936, 1938; Byers and Lakin, 1939; Lovering and others, 1956; Trites and Lakin, 1956; Williams and Lakin, 1935; Williams and others, 1940, 1941.

——— 1956, A field test for selenium: Internat. Geol. Cong., 20th, Mexico 1956, Resumenes Trabajos Presentados, p. 366–367.

A small, simple one-piece still for use in rapid field determination of selenium uses 1 gram of material, concentrated sulfuric acid, hydrobromic acid, and bromine. This method can detect as little as 50 ppm selenium immediately and on standing, as little as 10 ppm selenium.

Lakin, H. W., and Byers, H. G., 1941, Selenium occurrence in certain soils in the United States, with a discussion of related topics; sixth report: U. S. Dept. Agriculture Tech. Bull. 783, 27 p.

Cretaceous shales of California were examined and found to contain selenium, but not in large amounts. Data on the selenium content of the sea floor of the Gulf of California and of the Pacific Ocean off southern California are given. Investigations of a mildly seleniferous area in Clark County, Nev., of low selenium content of Permian formations of Oklahoma, and of Cretaceous areas of New Jersey, Maryland, and the District of Columbia, which contain minor amounts of selenium, are described. The soils of the Lower Brule Indian Reservation are derived from Pierre shales and contain 0.2 to 16 ppm selenium. The selenium content of atmospheric dust in cities was studied and found to vary from 0.05 to 10 ppm. The source of selenium is probably the pyritic material in coal. A discussion of the modes of accumulation of selenium is presented.

Lakin, H. W., and Byers, H. G., 1948, Selenium occurrence in certain soils in the United States, with a discussion of related topics; seventh report: U. S. Dept. Agriculture Tech. Bull. 950, 36 p.

The report contains analyses of selenium content of soils, minerals, and vegetation of northeastern North Dakota, and areas of Utah, Nevada, Idaho, and Oregon and analyses of 98 samples of pyrite and sulfide ores. Investigation of soils and vegetation of the Park City region, Utah, shows that mine residue slimes deposit selenium in the soils of the valley along Silver Creek. One sample of ore from Park City contained 540 ppm selenium; the slimes contained an average of 70 ppm selenium.

Lakin, H. W., Williams, K. T., and Byers, H. G., 1938, "Nontoxic" seleniferous soils: Indus. Eng. Chemistry, Indus. Ed., v. 30, p. 599–600.

Vegetation grown on soils in Hawaii and Puerto Rico is not seleniferous. Selenium may be present in soils in three forms which become available to plants only by slow processes of hydrolytic action: (a) free selenium, (b) pyritic selenium, and (c) basic ferric selenite. Soils of Hawaii and Puerto Rico are highly ferruginous, and the selenium in such soils is insoluble and does not produce toxic vegetation.

Landergren, Sture, 1935, Kännedomen om vara sulfidmalmers geokemi: Geol. fören. Stockholm Förh., v. 57, H. 4, p. 626–636.

Two samples of breccia ores from Saxberg and Garpenberg, Sweden, containing 11 percent zinc and much pyrrhotite, contained less than 1 and 100 ppm selenium, respectively.

Laney, F. B. *See* Bastin and Laney, 1918; Emmons and Laney, 1926; Piper and Laney, 1926.

Lausen, Carl, 1928, Hydrous sulphates formed under fumarolic conditions at the United Verde mine: Am. Mineralogist, v. 13, no. 6, p. 203–229.

Minerals formed as the result of a fire at the United Verde mine, Jerome, Ariz., included a black substance which occurs as a coating on fragments of rock beneath iron hoods placed over vents where sulfur dioxide gas issues. The material was found to be sulfide of arsenic with selenium ($As(S,Se)_2$).

Lenher, Victor, 1923, Occurrence, chemistry, and uses of selenium and tellurium (with discussion): Am. Inst. Mining Metall. Engineers Trans., v. 69, p. 1035–1057; abs., Mining and Metallurgy, v. 4, p. 32–33.

Discussion of analytical chemistry of selenium including descriptions of methods for oxidized compounds, precipitation tests, qualitative detection in complex mixtures, quantitative methods, separation of selenium and tellurium, and analytical methods practiced at refineries. Brief paragraphs on occurrence and uses.

Levine, V. E., 1915, Biochemical studies of selenium: New York Acad. Sci. Annals, v. 26, p. 385–394.

Describes reduction of selenium compounds such as selenious acid, selenic acid, and sodium selenate, by chemical substances, micro-organisms, plant substances, and animal tissues.

Levine, V. E., 1925, The reducing properties of microorganisms with special reference to selenium compounds: Jour. Bacteriology, v. 10, p. 217–262.

In the presence of living bacteria, selenious acid, selenic acid, and sodium selenite were reduced to free red selenium. Sodium selenate was not reduced to free selenium. The reduction of selenium is directly proportional to the rate of growth of the organism.

Lindgren, Waldemar, 1905, The copper deposits of the Clifton-Morenci district, Arizona: U. S. Geol. Survey Prof. Paper 43, p. 39, 108.

There is a very small amount of selenium in the ores; flue dust from the Detroit Copper Company's smelters averaged 0.0125 percent selenium-tellurium; matte averaged 0.013 percent selenium-tellurium.

——— 1909, Comments on selenium: Science, v. 30, p. 972.

Gold-quartz veins in Tertiary andesitic rocks and tuffs in the Republic district, Wash., contain concentric crusts of quartz, chalcedony, and opal with dark streaks of antimonial tetrahedrite and chalcopyrite. These are rich in gold and carry one percent of selenium, probably combined with the gold. These rare Tertiary selenide veins are similiar to those at Tonopah, Nev.

——— 1915, Geology and mineral deposits of the National mining district, Nevada: U. S. Geol. Survey Bull. 601, p. 32.

Tertiary rhyolite flow at the summit of Buckskin Peak shows hot-spring action with the development of chalcedony and silicified rhyolite, in which were found reddish-brown spots giving a strong reaction for selenium.

——— 1933, Mineral deposits: 4th ed., New York, McGraw-Hill, p. 496–498.

Selenium is present in pyritic copper ores of the Mansfeld district, Germany, in small veins in pre-Cambrian rocks at Falun and Skrikerum, Sweden, and in Paleozoic rocks in the Harz, Germany. It occurs more commonly in epithermal quicksilver, silver-lead, and gold-silver veins. Banded veins of gold and selenides, free from other ore minerals, occur in a fine-grained quartz gangue at Republic, Wash., and Radjang Lebong, Sumatra. The gold is finely distributed and the gold selenide has not been positively identified. The veins have probably been deposited close to the surface as colloids.

Loughlin, G. F. *See* Butler and others, 1920.

Love, J. D., 1954, Preliminary report on uranium in the Gas Hills area, Fremont and Natrona Counties, Wyoming: U. S. Geol. Survey Circ. 352, 11 p.

In the Gas Hills area uranium minerals occur in the Wind River formation of early Eocene age in the Thermopolis shale of early Cretaceous age. The uranium is concentrated in clayey and conglomeratic sandstone and in carbonaceous shale. The source of the uranium may have been tuff in the White River formation or younger Tertiary rocks that once overlaid the area. Uranium was carried downward and laterally along sandstone aquifers and was concentrated in favorable host rocks. Eleven samples were analyzed for selenium, and contained from 2 to 80 ppm. The Lysite area, 30 miles north of Gas Hills, is an area of highly seleniferous tuffaceous strata of middle and late Eocene age. The significant feature of the Lysite occurrence is the large amount of water-soluble selenium.

Lovering, T. S., Lakin, H. W., Ward, F. N., and Canney, F. C., 1956, The use of geochemical techniques and methods in prospecting for uranium, *in* Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U. S. Geol. Survey Prof. Paper 300, p. 659–665.

Describes a method for semiquantitative determination of selenium in soils, rocks, and vegetation containing from 2 to 100 ppm selenium. The method, which is not suitable for field use, is a microchemical adaptation of the distillation procedure of Hillebrand and others, combined with Franke's confined spot method of estimation.

Lundell, G. E. F. *See* Hillebrand and others, 1953.

McAllister, J. F., and Hernandez Ortiz, David, 1945, Quicksilver-antimony deposits of Huitzuco, Guerrero, Mexico: U. S. Geol. Survey Bull. 946–B, p. 63.

Tiemannite, onofrite, and other rare selenides of mercury, antimony, and thallium are reported in the Huitzuco ore.

McCaskey, H. D., 1912, Quicksilver: U. S. Geol. Survey Mineral Resources U. S., 1911, pt. 1, p. 914–915.

The Lucky Boy quicksilver mine, 5 miles southwest of Marysvale, Piute County, Utah, lies on a steep fault scarp on the east side of the Tushar Range. The commercial ore was mainly onofrite and tiemannite, the sulfo-selenide and selenide of mercury, which occurred in a deposit from 2 to 8 inches thick, following the bedding planes and impregnating impure dark gray limestone. Tiemannite also was present in a vein carrying barite and cinnabar.

McCreary, O. C. *See* Beath and others, 1934a.

McCrosky, C. R. *See* Coleman, W. C., and McCrosky, 1937.

McCullough, J. D., Campbell, T. W., and Krilanovich, N. J., 1946, Analysis of organoselenium compounds: Indus. Eng. Chemistry, Anal. Ed., v. 18, p. 638–639.

Description of method for determining selenium content of organic compounds.

Machatschki, F., and Stradner, E., 1952, Ein Selenid-Mineral vom Spinneltyp: Österreich. Akad. Wiss., math.-nat. Kl., v. 89, p. 211–214.

Crystallographic study of cobalt selenide minerals and selenides of the spinel group.

McNulty, J. S., 1947, Routine method of determining selenium in horticultural materials: Indus. Eng. Chemistry, Anal. Ed., v. 19, p. 809–810.

Description of a method for determining selenium content of organic matter.

Mallet, J. W., 1878, On the chemical composition of guanajuatite, or selenide of bismuth, from Guanajuato, Mexico: Am. Jour. Sci., ser. 3, v. 15, p. 294–296.

Analysis of the mineral guanajuatite gives the formula Bi_2Se_3 with varying amounts of sulfur replacing selenium.

Margrave, J. L. *See* Elkin and Margrave, 1954.

Marvin, G. G., and Schumb, W. C., 1935, The determination of small quantities of selenium in sulfur: Indus. Eng. Chemistry, Anal. Ed., v. 7, p. 423–425.

Description of a method for determining amounts of selenium ranging from 0.1 to 0.001 percent in sulfur. Commercial sulfur from Texas, crude Louisiana sulfur, and crystal sulfur from Garginti, Italy, contained no selenium; Sicilian selenosulfur of volcanic origin contained 0.054 percent selenium.

Mason, Brian, 1952, Principles of geochemistry: New York, Wiley, p. 41, 154, 167, 172, 173, 197, 200.

A review of the cycle of selenium in sea water and its removal by adsorption on freshly precipitated ferric hydroxide, which is shown by the presence of selenium in larger amounts in sedimentary iron ores than its average abundance in the earth's crust. The total amount of selenium supplied to sea water is 0.054 ppm; the amount present is 0.004 ppm. The ability of certain plants to absorb large amounts of selenium is mentioned.

Mathews, J. A., Curl, A. L., and Osborn, R. A., 1937, Report on selenium: Assoc. Official Agr. Chemists Jour., v. 20, no. 2, p. 194–202.

Description of procedures of sample preparation, isolation of selenium, and methods of determining selenium.

Matteucci, R. V., and Giustiniani, E., 1897, Il selenio nei prodotti delle fumarole dell'eruzione Vesuviana del 3 luglio 1895: Reale Accad. sci. fis. e mat. Napoli, Rend. ser. 3a, v. 3, p. 100–101.

Analysis of the products of a fumarole on the northwest flank of Vesuvius which erupted on July 3, 1895. In addition to the elements usually found, there were fluorine, phosphorous, boron, and red incrustations of selenium.

Mellor, J. W., 1930, A comprehensive treatise on inorganic and theoretical chemistry: London, Longmans, Green and Co., v. 10, p. 693–932.

A treatise on the history, occurrence, extraction and purification, allotropic forms, physical and chemical properties, and compounds of selenium.

Mellquist, H. *See* Klason and Mellquist, 1912a, b.

Merwin, H. E. *See* Hillebrand and others, 1914.

Meyer, Julius, and Bratke, Herbert, 1924, Zur Kenntnis der Doppelselenide. 1. Die natürlich verkommenden Doppelselenide: Zeitschr. anorg. allg. Chemie, v. 135, no. 3, p. 289–296.

Analyses are given for umangite, eucairite, zorgite, lehrbachite, and crookesite.

Miesch, A. T., and Connor, J. J., 1956, Distribution of elements, *in* Geologic investigations of radioactive deposits—Semiannual progress report, Dec. 1, 1955, to May 31, 1956: U. S. Geol. Survey TEI–620, issued by U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn., p. 128–146.

Report on investigation of the distribution of minor elements in the Salt Wash sandstone member of the Morrison formation to determine which are most useful in tracing patterns of metal dispersion around uranium deposits. Samples were collected in and near the Blitz and Joe Dandy mines in the Henry Mountains mining district, Utah. Most of the samples taken more than a few feet away from the uranium deposits contain less than 1 ppm selenium. Thus, the presence or absence of selenium in rock samples is not a useful guide to uranium ore.

Miller, J. T. *See also* Byers and other, 1938.

——— 1937, Selenium in plants in relation to its occurrence in soils: Jour. Agr. Research, v. 55, p. 59–68.

Plants are classified into three types in relation to their tolerance of selenium in the soil: (a) those that absorb selenium readily; (b) that are able to absorb moderate or large amounts of selenium without severe injury; and (c) that have very limited tolerance of selenium and absorb only small quantities.

Miller, J. T., and Brown, I. C., 1938, Observations regarding soils of northern and central Mexico: Soil Sci., v. 46, p. 427–450.

Analyses of soils in northern and central Mexico indicate the presence of selenium only in the Irapuato, Guanajuato, soils, chiefly in the upper 10 inches. Selenium is derived from mine slimes which wash down into the valley. The selenium content averaged from 0.01 ppm at a depth of 144 inches to 1.5 ppm at from 0 to 10 inches.

Miller, J. T., and Byers, H. G., 1935, A selenium spring: Indus. Eng. Chemistry, News Ed., v. 13, p. 456.

Water from a temporary spring in the Niobrara formation in T. 6 S., R. 7 E., Custer County, S. Dak., and soil and vegetation in the neighborhood were analyzed for selenium. The water contained 0.4 ppm selenium, the soil contained 1.5 to 4.0 ppm selenium, the vegetation contained as high as 1600 ppm selenium. Water from another spring in T. 36 N., R. 47 W., contained 0.07 ppm selenium.

Milligan, W. E., 1953, Selenium and tellurium, *in* Modern uses of nonferrous metals: 2d ed., Am. Inst. Mining Metall. Engineers, p. 333–365.

Describes isotopes, occurrence, properties, toxic effects, extraction, economics, and uses of selenium.

Minami, E., 1935, Selen-Gehalte von europäischen and japanischen Tonschiefern: Gesell. Wiss. Göttingen Nachr., math.-phys. Kl., v. 4, new ser., v. 1, no. 12, p. 143–145.

Selenium content of European Paleozoic and Japanese Mesozoic clay shales was determined by the method of Goldschmidt and Strock. The selenium contents varied somewhat, but the atomic ratio of sulfur to selenium was approximately 10,000:1 for all three. (Chem. Abs., v. 30, col. 1335.)

Mining Journal, 1953, Selenium—a scarce by-product metal: Mining Jour. [London], v. 241, no. 6185, p. 241–242.

Describes occurrence, uses, recovery processes, and supplies of selenium.

Moore, B. N. *See* Hewett and others, 1936.

Moore, R. T., 1953, Minerals and metals of increasing interest. Rare and radioactive minerals: Arizona Bur. Mines Bull. 163, p. 17–19.

A review of the general features, minerals, and occurrence of selenium. At Jerome, Yavapai County, Ariz., crystals of selenium nearly 1 inch long have been found in the fire zone of the United Verde mine. Soils in the vicinity of Camp Verde and also in the upper Tonto Valley are known to contain selenium, but percentages present are not available.

Mosher, M. A., 1933, Recovery of precious and secondary metals from electrolytic copper refining: Am. Inst. Mining Metall. Engineers Trans., v. 106, p. 427–440.

Raw electrolytic slime at Raritan Copper Works, Perth Amboy, N. J., contains 5.31 percent selenium. Selenium recovery plant is capable of producing 3,000 pounds of powdered selenium per month.

Moxon, A. L. *See also* Olson and Moxon, 1939; Olson and others, 1940, 1942a, b; Searight and Moxon, 1945; Searight and others, 1946, 1946–47.

——— 1937, Alkali disease or selenium poisoning: South Dakota Agr. Expt. Sta. Bull. 311, 91 p.

Geological and geographical distribution of selenium in South Dakota and the United States, factors affecting selenium content of soils and plants, and methods of analysis are described. The source of the selenium is believed to be volcanoes of the Cordilleran Geanticline active during the Mesozoic era. Selenium may have been a constituent of the magmas or it may have been conveyed by winds with gases and ash and deposited with sedimentary materials in the Mesozoic seas which covered the Great Plains. In support of this hypothesis is the fact that zones high in selenium also contain bentonite which is presumed to be derived from volcanic ash. In South Dakota, the Pierre and Niobrara formations are the most seleniferous and the soils derived from these formations are heavy clay or gumbo soils. Map and table show distribution and selenium content of Cretaceous formations of South Dakota.

Moxon, A. L., and Rhian, Morris, 1943, Selenium poisoning: Physiol. Rev., v. 23, no. 4, p. 305–337.

Review of literature on the geological distribution of selenium in the Cretaceous formations of Western United States, selenium content of soils, absorption of selenium by plants, and selenium poisoning in animals.

Moxon, A. L., Olson, O. E., and Searight, W. V., 1939, Selenium in rocks, soils and plants: South Dakota Agr. Expt. Sta. Tech. Bull. 2, 94 p.

Analyses of seleniferous formations in South Dakota are given. The Niobrara formation is the most consistently highly seleniferous formation. The Sharon Springs member, the upper part of the Virgin Creek member, and the Interior (Mobridge) member of the Pierre formation are also highly seleniferous. Factors determining surface distribution of selenium are width of outcrop, creeping of beds, alluvial deposition, leaching, and secondary deposition. During the formation of soils from bedrock there is considerable loss of selenium by leaching, surface runoff, mixing of parent materials, and topography as it affects surface runoff. Factors determining the availability of selenium to plants are the kind of plants present and their stage of growth, chemical form of the selenium, total selenium content of the soil, climate, and others. Selenium contents of grasses and converter plants in South Dakota are compared. In general, the selenium content of formations determines the type of plants and the selenium content of the plants. A hypothetical selenium cycle is presented.

Moxon, A. L., Olson, O. E., Searight, W. V., and Sandals, K. M., 1938, The stratigraphic distribution of selenium in the Cretaceous formations of South Dakota and the selenium content of some associated vegetation: Am. Jour. Botany, v. 25, no. 10, p. 794–809.

Selenium occurs in all Cretaceous formations in South Dakota from the Dakota sandstone through the Pierre formation. Selenium content is low in the Dakota, Graneros, Greenhorn, and Carlile formations, the Fort Hays member of the Niobrara formation, and the Sully and Virgin Creek members of the Pierre formation; high in the Smoky Hill member of the Niobrara formation and the Sharon Springs member of the Pierre formation; and locally high in thin parts of the Mobridge member of the Pierre formation. There is a close relationship between formation, type of vegetation, and selenium content of vegetation.

Muñoz Reyes, Jorge. *See* Ahlfeld and Muñoz Reyes, 1938, 1939, 1955.

Murdoch, Joseph, and Webb, R. W., 1956, Minerals of California: California Div. Mines Bull. 173, p. 150, 239, 327.

Localities where selenium minerals have been found in California are described. These include naumannite from the Idaho–Maryland mine, Grass Valley, Nevada County; tiemannite from Clear Lake and Abbott mine, Lake County, Helen mine and San Joaquin Ranch mine, Orange County, Guadalupe mine, Santa Clara County, and Socrates mine, Sonoma County; eucairite at Willard Mining Company property, Murphys district, Calaveras County.

Murray, R. M., 1933, Electrolytic copper refining at Mount Lyell, Tasmania: Am. Inst. Mining Metall. Engineers Trans., v. 106, p. 415.

Analyses of tank house materials in 1932 gave 0.031 percent selenium in anodes, 2.83 percent selenium in slimes.

Muthmann, Wilhelm, 1890, Untersuchungen über den Schwefel und das Selen: Zeitschr. Krystallographie u. Mineralogie, v. 17, p. 336–367.

Crystallographic forms of selenium, mixed sulfur-selenium crystals, and metallic selenium are described.

Nakagawa, Yasuharu. *See* Ishibashi and others, 1953.

Newberry, J. S., 1881, The Silver Reef sandstones: Eng. Mining Jour., v. 31, p. 4–5.

Four analyses of ore from Silver Reef, Utah, gave an average of 0.23 percent selenium and 0.26 percent silver. In one specimen the selenium content was 90 ounces per ton.

Noddack, Ida, 1936, Über die Allgegenwart der chemischen Elemente: Angew. Chemie, v. 49, p. 835–841.

A theory that all minerals contain minute amounts of all chemical elements is presented. Mansfeld copper shale contained 0.03 percent selenium and sphalerite from Silesia contained 0.04 percent selenium.

Nolan, T. B. *See* Hewett and others, 1936.

Nordenskiöld, A. E., 1867a, Die Selenmineralien von Skrikerum: Jour. prakt. Chemie, v. 102, p. 456–458.

The minerals eucairite, berzelianite, and crookesite from the copper mine at Skrikerum are described. The thallium content of the minerals is discussed. Eucairite and berzelianite contain very little thallium, while crookesite contains about 16 percent thallium.

Nordenskiöld, A. E., 1867b, Sur les minéraux séléniféres et thalliféres de Skrikerum: Soc. chim. France Bull., ser. 2, v. 7, p. 409–414.

First selenium minerals found at Skrikerum copper mine were eucairite and berzelianite. Crookesite was found later by the author.

Nordström, Th., 1879, Mineralanalytiska bedrag; 2—Selenhaltigt mineral från Falun: Geol. fören. Stockholm Förh., v. 4, p. 268.

Description of a bismuth lead selenide mineral found at Falun, Sweden.

——— 1880, Mineralanalytische Beiträge—Selenmineral von Falun: Zeitschr. Krystallographie u. Mineralogie, v. 4, p. 526.

Selenium minerals from Falun, Sweden, are described.

O'Connor, R. *See* Walsh and others, 1951.

Ödman, O. H. *See also* Grip and Ödman, 1942.

——— 1938, On the mineral associations of the Boliden ore: Stockholms Högskolas mineralog. inst. Medd., v. 60, no. 2, no. 98, p. 121–146.

A general description of the ore and minerals of the Boliden mine. Selenium is found in varying but small amounts; a number of minerals including selenides are as yet unidentified by the author.

——— 1941, Geology and ores of the Boliden deposit, Sweden: Sveriges Geol. Undersökning, Ser. C, no. 438, Årsb. 35, no. 1, 190 p.

A lead-bismuth-sulfo-selenide mineral occurs in large quantities intergrown with galena in the quartz-tourmaline ore at Boliden. It is called selenocosalite. A mineral similar to kobellite but containing large amounts of selenium also occurs in the quartz-tourmaline veins; it is called selenokobellite.

Olivares S., F. E., and Girón B., I. N., 1956, Recuperación de metales raros en la fundición de la Oroya: Minería [Peru], v. 5, no. 16, p. 2–11.

Selenium recovery at La Oroya smelter of Cerro de Pasco Corp., Peru, is described. Eighty percent of the selenium entering the smelter is in lead concentrates and the remainder is in copper concentrates. The Casapalca mine produces 90 percent of the lead concentrates, which contain 0.09 percent selenium; the copper concentrates come from the Cerro, Yauricocha, and Morococha mines and contain 0.01 percent selenium. A large part of the selenium which enters the smelter in lead concentrates emerges in the residue of the electrolytic refining of copper. The metallurgy of selenium is described and flow sheets showing the recovery of selenium at La Oroya are pictured.

Olsacher, Juan, 1927, Über ein neues Vorkommen von Umangit: Zentralbl. Mineralogie, Jahrg. 1927, Abt. A, no. 5, p. 170–172.

Zorgite from Zorge, Germany, was found to consist of umangite, clausthalite, and an unknown green mineral; zorgite from Tilkerode, Germany, consisted of umangite and clausthalite only. "Selenquecksilberkupferblei" from Zorge was found to be composed of clausthalite, umangite, and tiemannite.

Olson, O. E. *See also* Moxon and others, 1938, 1939.

Olson, O. E., and Moxon, A. L., 1939, The availability to crop plants of different forms of selenium in the soil: Soil Sci., v. 47, p. 305–311.

Most of the seleniferous soils in South Dakota are derived from the Pierre formation. The availability of selenium to plants depends on the amount of water soluble selenium, which in turn depends on the amount of selenium in the organic fraction of the soil.

Olson, O. E., Jornlin, D. F., and Moxon, A. L., 1942a, Field studies on methods for determining availability of selenium to plants: Soil Sci., v. 53, no. 5, p. 365–368.

In field studies on naturally seleniferous soils it has been found that no correlation exists between selenium content of *Astragalus* and the total, water-soluble, or base-soluble selenium content of the first foot of soil. Soils in which the leaching of selenium is apparently greater seem to produce plants with a higher selenium content, and it appears that much selenium is absorbed from the subsurface soils.

Olson, O. E., Sisson, L. L., and Moxon, A. L., 1940, Absorption of selenium and arsenic by plants from soils under natural conditions: Soil Sci., v. 50, no. 2, p. 115–118.

No correlation between selenium and arsenic content of soils in South Dakota was noted. Arsenic content of the soils studied was greater than selenium content, but plants grown in the soils contained more selenium. Selenium was present in a more available form than arsenic.

Olson, O. E., Whitehead, E. I., and Moxon, A. L., 1942b, Occurrence of soluble selenium in soils and its availability to plants: Soil Sci., v. 54, no. 1, p. 47–53.

Analyses of plants and soils from T. 107 N., R. 78 W., South Dakota, indicate that soil at 2 or 3 feet in depth, rather than the top 1 foot, is the source of "available" selenium to plants. During weathering of rock to soil, a large part of the selenium is oxidized to the soluble selenate form and is leached from the surface to the subsurface soils, or to soils at lower elevations.

Osborn, R. A. *See* Curl and Osborn, 1938; Mathews and others, 1937.

Otto, Robert, 1890, Eukairit aus Argentinien: Deutsche chem. Gesell. Ber., v. 23, p. 1039–1041.

Eucairite from La Rioja, Argentina, is described with analyses.

Painter, E. P. *See also* Franke and Painter, 1937.

——— 1941, The chemistry and toxicity of selenium compounds, with special reference to the selenium problem: Chem. Rev. [Baltimore], v. 28, p. 179–213.

Review of the forms of selenium in soil and plants, and selenium content of soils and plants. Discusses organic compounds, methods of analysis, and properties of selenium in plants.

Palache, Charles, 1934, Contributions to crystallography: Claudetite; minasragrite; samsonite; native selenium; indium: Am. Mineralogist, v. 19, p. 203.

Needles of native selenium were found as incrustations on quartzite and fire-fritted sandstone in the fire-zone of the United Verde mine, Jerome, Ariz. The crystals reach a length of 2 cm and a diameter of 1 mm.

Palache, Charles, 1937, Chalcomenite from Bolivia: Am. Mineralogist, v. 22, no. 6, p. 790–795.

A crystallographic study of chalcomenite, hydrous selenite of copper, from the Hiaco lead-silver mine, near Colquechaca, Bolivia. Chalcomenite occurs in cavities lined with limonite together with blockite (penroseite), cobaltomenite (ahlfeldite), and needles of selenolite at the Hiaco mine.

Palache, Charles, Berman, Harry, and Frondel, Clifford, 1944, The system of mineralogy of James Dwight Dana and Edward Salisbury Dana: 7th ed., New York, John Wiley and Sons, v. 1, p. 136–137, 142, 161–167, 178–180, 182–184, 194–195, 204–205, 215–218, 251, 278–279, 294–296, 451, 473–475, 595; v. 2, p. 635, 638–641.

Describes mineralogy and occurrence of selenium, selentellurium, seleniferous sulfur, tetradymite, gruenlingite, joseite, aguilarite, naumannite, berzelianite, eucairite, umangite, clausthalite, tilkerodite, zorgite, metacinnabar, guadalcazarite, onofrite, tiemannite, lehrbachite, klockmannite, guanajuatite, penroseite, blockite, wittite, weibullite, seleniferous galenobismutite, platynite, chiviatite, ahlfeldite, chalcomenite, cobaltomenite, kerstenite, molybdomenite, and selenolite.

Peacock, M. A., 1941, On joseite, grünlingite, oruetite: Univ. Toronto Studies, Geol. Ser., no. 46, p. 83–103.

Joseite from British Columbia and other areas does not contain selenium, while joseite from San José, Minas Geraes, Brazil, contains from 1.46 to 1.48 percent selenium. Selenium is found in these specimens to substitute for tellurium in a general formula.

Peacock, M. A., and Berry, L. G., 1940, Röntgenographic observations on ore minerals: Univ. Toronto Studies, Geol. Ser., no. 44, p. 47–69.

Guanajuatite from Guanajuato, Mexico, gave X-ray pattern similar to those of bismuthinite and stibnite and very different from that of artificial Bi_2Se_3. Weibullite, seleniferous galenobismutite, and seleniferous chiviatite from Falum, Sweden, give varying proportions of lead, bismuth, selenium, and sulfur, with copper and iron. These minerals are shown by polished sections and X-ray powder photographs to be essentially alike, being intimate intergrowths of two undetermined white metallic minerals, with associated chalcopyrite.

Penfield, S. L., 1885, Crystallized tiemannite and metacinnabarite: Am. Jour. Sci., ser. 3, v. 29, no. 174, p. 449–454.

Presents crystallographic measurements and chemical analyses of tiemannite from Marysvale, Utah. The mine from which the tiemannite was taken is described by J. E. Clayton as being situated on the east face of a mountain slope and near a profound fault extending north and south. To the east are eruptive rocks including porphyry and trachyte. Underlying the ore beds to the west is quartzite overlaid by 400 feet of gray limestone. The Deertrail vein, carrying gold, silver, lead, and a little copper, is situated at the contact between the quartzite and limestone. In the upper part of the limestone the selenide of mercury is found in a bed of shaly limestone from 15 to 20 feet thick. The vein has been traced north and south about 100 feet along the outcrop and dips into the mountain at an angle of 15°. The ore occurs in masses intermixed with shaly limestone, crystals being very rare. The accompanying minerals are barite, oxide of manganese, quartz, and calcite. The relationship between selenides and sulfides of mercury is discussed.

Petersen, Theodor, 1872, Guadalcazarit, ein neues Mineral (Schwefel-Selen-Zink-Quecksilbererz: Mineralog. Mitt., Jahrg. 1872, no. 2, p. 69–70.

Description of guadalcazarite from Guadalcazar, Mexico, associated with cinnabar in a quartz and barite gangue.

Peterson, H. E. *See also* Sill and Peterson, 1954.

Peterson, H. E., Jensen, C. L., and Anderson, R. G., 1957, A field test for selenium: U. S. Bur. Mines Rept. Inv. 5328, 7 p.

Two methods for qualitative detection of selenium in rocks and soils are described. Both methods are sensitive to 10 ppm selenium and can be made semiquantitative by using suitable standard samples. Fusion with potassium pyrosulfate and a reducing agent can be used if the sample does not contain sulfur or carbonaceous material which, if not oxidized, interfere with the detection of selenium. Caustic fusion with sodium peroxide and sodium hydroxide before fusion with potassium pyrosulfate insures complete oxidation of the sample if sulfur or carbonaceous material are abundant.

Pilipenko, P. P., 1910, Selenium in Altai minerals: Acad. sci. St. Pétersbourg Bull. 1909, p. 1113–1115.

Two specimens of galena contained 1.17 and 1.23 percent selenium, and a specimen of antimony-copper sulfide contained 0.13 percent selenium. (Chem. Abs., v. 4, p. 2787.)

Piper, A. M., and Laney, F. B., 1926, Geology and metalliferous resources of the region about Silver City, Idaho: Idaho Bur. Mines and Geology Bull 11, 165 p.

The silver deposits of the Silver City district are quartz-filled fissure veins and breccia veins. Naumannite and argentite, as they occur in the Silver City district, have identically the same physical properties. It is probable that of the two, naumannite was and is by far the more abundant. Much of the mineral previously called argentite was in reality naumannite. Naumannite is a late hypogene mineral, and may be supergene in some cases. It occurs in the De Lamar, Trade Dollar, Alpine, Banner, and Poorman veins. Clausthalite was found as a minor accessory mineral in the Trade Dollar vein.

Pisani, F., 1879, Sur divers séléniures de plomb et de cuivre de la Cordillière des Andes: Acad sci. [Paris] Comptes rendus, v. 88, p. 391–392.

Lead-copper selenides found as accessory minerals in an unidentified lead mine of Peru were analyzed. The selenides were of two distinct types and were associated with azurite, malachite, and chrysocolla. Analyses showed selenides corresponding to the formulas $(Pb, Cu) Se$ and $(Cu,Pb)_3Se_2$ with traces of cobalt, iron and silver.

Powell, A. R. *See* Schoeller and Powell, 1920.

Prichard, G. E. *See* Vine and Prichard, 1954.

Pugsley, C. W., and Cox, T. H., 1937, Selenium problems in South Dakota: Brookings, South Dakota State Planning Board, 30 p.

Properties, occurrence, and distribution of selenium in South Dakota; effects of rainfall on selenium content of soils, poison springs; and selenium convertor plants are discussed. Analyses of soil samples for selenium content show that soils formed from rocks of the Pierre and Niobrara formations are the most seleniferous. Report also contains results of investigation of selenium in the Fort Randall area and a map showing toxic areas of South Dakota.

Quercigh, Emanuele, 1925, Sul solfoselenio di Vulcano (Isole Eolie): Reale Accad. sci. fis. e mat. Napoli, Rend., v. 31, p. 65–69.

Selensulfur occurs as thin adherent layers in strongly altered siliceous rock. It is amorphous, vitreous, of a brownish-red color, with a conchoidal fracture and reddish streak. The mineral contains traces of arsenic and tellurium. Selensulfur also occurs in an opaque orange-yellow crystal phase which is probably derived from the amorphous phase. Analyses of the soluble portion gave 98.71 percent sulfur, 1.03 percent selenium, 0.18 percent tellurium; and 99.06 percent sulfur, 0.83 percent selenium, and no tellurium. Caution is necessary not to confuse real selensulfur with other products of fumarole activity around Vulcano which have a similar appearance, but which consist mostly of sulfur and arsenic with subordinate amounts of selenium and tellurium. (Chem. Abs., v. 20, p. 2804.)

Rader, L. F., Jr., and Hill, W. L., 1935, Occurrence of selenium in natural phosphates, superphosphates, and phosphoric acid: Jour. Agr. Research, v. 51, no. 12, p. 1071–1083.

Selenium occurs in quantities from less than 0.1 ppm in Tennessee brown phosphate rock to 55 ppm in Wyoming and Algerian phosphates. Phosphate rock from Florida, Tennessee (except Tennessee blue rock), Kentucky, Arkansas, Oklahoma, Australia; light-colored phosphates from Western United States; and apatites from Virginia and Canada contained 1 ppm or less of selenium. Dark-colored phosphates from Western United States and Canada, the majority of Tennessee blue rock and South Carolina phosphates, and Africa and Palestine phosphates contained from 1 to 55 ppm selenium. Larger amounts of selenium occur in pyritiferous phosphates and in phosphates containing greater amounts of organic material. Primary phosphate deposits contain about 5 times as much selenium as secondary phosphate deposits. Permian deposits contain the largest amount of selenium, followed by Miocene, Cretaceous, Jurassic, Eocene, Devonian, and post-Tertiary deposits. Only a small amount of the selenium in raw phosphate rock finds its way into superphosphates and phosphoric acid.

Ramdohr, Paul, 1928, Klockmannit, ein neues natürliches kupferselenid: Zentralbl. Mineralogie, Jahrg. 1928, Abt. A, no. 7, p. 225–232.

Describes analyses of klockmannite from Sierra de Umango, Argentina; Lehrbach, Harz Mountains, Germany; and Skrikerum, Sweden.

——— 1937, Erzmikroscopische Untersuchungen an einigen seltenen oder bisher wenig beachteten Erzmineralien: Zentralbl. Mineralogie, Jahrg. 1937, Abt. A, no. 10, p. 289–293.

Crystallographic description of villamaninite from the Carménes mine, near Villamanin, Léon, Spain.

——— 1948, Les especes mineralogicas guanajuatite y paraguanajuatite: México Com. Directivo Inv. Recursos Minerales Bol. 20, p. 1–15.

Discussion of mineralogy and occurrence at Guanajuato of guanajuatite and paraguanajuatite.

Ramdohr, Paul, 1949, Neue Erzmineralien: Fortschr. Mineralogie, v. 28, p. 69–70.

Eskebornite from Tilkerode, Harz Mountains, Germany, is described.

——— 1956, Stilleite, ein neues Mineral, naturliches Zinkselenid, von Shinkolobwe, *in* Lotze, Franz, Geotektonisches Symposium zu Ehren von Hans Stille: Stuttgart, F. Enke, p. 481–483.

A new zinc selenide mineral, stilleite, was found in an ore sample from Shinkolobwe, Belgian Congo, associated with pyrite, linneite, clausthalite, two unidentified minerals, and dolomite. The mineral is cubic, of the sphalerite type, isotropic, and the color resembles that of tetrahedrite.

Ramdohr, Paul, and Schmitt, Marg., 1955, Vier neue natürliche Kobaltselenide vom Steinbruch Trogtal bei Lautenthal im Harz: Neues Jahrb. Mineralogie, Monatsh., Jahrg. 1955, no. 6, p. 133–142.

Four new cobalt selenide minerals occur in violet to red-brown intergrowths in clausthalite; hematite and secondary native selenium are also present. The minerals are trogtalite ($CoSe_2$), hastite ($CoSe_2$ or CoAsSe), bornhardtite (Co_3Se_4), and an unnamed mineral too scarce to study.

Rankama, Kalervo, and Sahama, Th. G., 1949, Geochemistry: Chicago, University of Chicago Press, p. 743–755.

Selenium is chalcophile and is enriched in sulfide ore bodies. It forms selenides and sulfoselenides of silver, copper, bismuth, mercury, and lead in hydrothermal rocks; selenites of copper, cobalt, and lead; selenates; and also occurs as native selenium, selen-tellurium, as the oxide, and with volcanic sulfur. Selenium is absorbed in plants, animals, bacteria, and coal. Cycle of selenium: it is removed from sea water with depositing oxidate sediments which are able to adsorb selenium nearly quantitatively from aqueous solutions. During the weathering of seleniferous sulfide deposits selenium is oxidized to selenite; in sediments where the redox potential is very high selenium is oxidized to selenate. Both selenates and selenites are readily reduced to selenium and various selenides.

Rhian, Morris. *See* Moxon and Rhian, 1943.

Roach, Carl. *See* Thompson, M. E., and others, 1956.

Roberts, R. J., 1940, Quicksilver deposit at Buckskin Peak, National mining district, Humboldt County, Nev.: U. S. Geol. Survey Bull. 922–E, p. 127.

Selenium is found in small reddish-brown spots in cinnabar-bearing siliceous sinter deposited by hot springs.

Robinson, S. C., 1950, Mineralogy of the Goldfields district, Saskatchewan: Canada Geol. Survey Paper 50–16, 38 p.

Selenium minerals are found in the uranium deposits of the Goldfields district, which are basically veins containing hematite, pitchblende, and gangue. The selenide deposits are unimportant in amount as compared with other types of deposits here, but they are of interest because of their size and because selenium is associated with uranium deposits at Theano Point on Lake Superior and in the Western United States. Selenides are found in the western part of the Goldfields–Martin Lake area only, from the Gil group northward through Martin Lake and Ato Bay to Hal Lake and the Stream fault. The Hal Lake and Ato Bay deposits are not radioactive and are small bodies of massive selenides which include umangite, klockmannite, and berzelianite, with some clausthalite, chalcomenite, and native copper. The selenides cement and partly replace brecciated host rock and are largely free of gangue minerals. Selenides are associated with pitchblende at Martin Lake mine in the Eagle group and in the Gil group, where they surround and cement fractures in the pitchblende. The selenides are associated with calcite, and where they are plentiful, sulfides are scarce or lacking. The selenides were deposited later than pitchblende, arsenides, or sulfides. The presence of native copper and selenides indicates a temperature of deposition below 200° C. Tiemannite has been found in the Nicholson No. 2 zone, and clausthalite is abundant in the Ace shaft.

Robinson, S. C., and Brooker, E. J., 1952, A cobalt-nickel-copper selenide from the Goldfields district, Saskatchewan: Am. Mineralogist, v. 37, p. 542–544.

A new cobalt-nickel-copper selenium mineral occurring in disseminated grains and small masses and resembling pentlandite was found with umangite, klockmannite, berzelianite, clausthalite, pyrite, hematite, and chalcopyrite at the Eagle group of claims and Ato Bay, Beaverlodge Lake, Goldfields district, Saskatchewan. The minerals cement sheared and fractured host rocks. The principal alteration product is chalcomenite.

Robinson, W. O., 1933, Determination of selenium in wheat and soils: Assoc. Official Agr. Chemists Jour., v. 16, p. 423–424.

A method for determining very small quantities of selenium in wheat and soil is described. One sample of soil contained 0.3 ppm selenium; 5 and 6 ppm selenium were found in samples of wheat.

——— 1936, Selenium content of wheat from various parts of the world: Indus. Eng. Chemistry, Indus. Ed., v. 28, p. 736–738.

Wheat from Saskatchewan, Canada, and South Africa contained from 1 to 2 ppm selenium, indicating seleniferous soils in those areas. Wheat from New South Wales, Australia; Spain; Argentina; and Canterbury, New Zealand contained less than toxic amounts of selenium.

——— 1945, Determination of total selenium and arsenic in soils: Soil Sci., v. 59, no. 1, p. 93–95.

A method for determining selenium in soil by quantitative distillation as bromide from strong hydrobromic acid solution. By this method it is possible to detect as little as 1 part of selenium in 10 billion parts of soil.

Robinson, W. O., and Edgington, Glen, 1945, Minor elements in plants, and some accumulator plants: Soil Sci., v. 60, no. 1, p. 15–28.

Variation in selenium content of plants is greater than that of any other element, and ranges from less than 0.1 to 14,900 ppm in *Astragalus racemosus*.

Robinson, W. O., 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. Eng. Chemistry, Anal. Ed., v. 6, p. 274–276.

Detailed descriptions of distillation procedures.

Rockenbauer, W., and Schroll, Erich, 1955, Ein empfindlicher spektrochemischer Nachweis von Selen in Erzen: Österreich. Akad. Wiss., math.-nat. Kl., v. 92, p. 192–196.

A spectrochemical method for determining selenium in sulfide minerals is described.

Rockenbauer, W., and Schroll, Erich, 1956, Spektrochemische Bestimmung des Selens in ostalpinen Pyriten—Dosaggio spettrochimico di selenio in piriti delle alpi orientali: Soc. mineralog. italiana Rend., v. 12, p. 194.

Sulfide ore minerals of the eastern Alps were analyzed for selenium. The highest value found was 0.01 percent in pyrite from Agordo, Italy.

Rose, Herm. *See* Geilmann and Rose, 1928.

Rossi, Michael. *See* Walker and others, 1941.

Rost, Rudolf, 1935, New minerals for Czechoslovakia from Kladno: Věda Přírodní, v. 16, p. 203–204.

The following occurred on burning heaps of Carboniferous sediments rich in pyrite: rhombohedral γ-selenium, letovicite, mascagnite, α-sulfur, copiapite, epsomite, hexahydrite, pickeringite, lapparentite, and organic substances—anthracene and fluorene. (Chem. Abs., v. 32, col. 885.)

——— 1937, The minerals in the burning shafts at Kladno: Česká akad. ved. Rozpravy, třídy 2, v. 11, p. 1–19.

Crystals of γ-selenium were found and many organic compounds were formed during the destructive disintegration of coal. (Chem. Abs., v. 33, col. 509.)

Rubey, W. W. *See* Hewett and others, 1936.

Runolinna, U. *See* Hukki and Runolinna, 1950.

Sahama, Th. G. *See* Rankama and Sahama, 1949.

Saito, Tadao, 1953, On minor elements in ore minerals of the Yakumo mine, Hokkaido, Japan: Hokkaido Univ. Fac. Sci. Jour., ser. 4, v. 8, p. 267–276.

The mineralization forming the lead-zinc-manganese deposits of the Yakumo mine in the Neogene Tertiary formation is divided into three stages. The chief minerals are quartz, rhodochrosite, galena, sphalerite, pyrite, and chalcopyrite. Selenium has been detected in rhodochrosite, galena, sphalerite, and in pyrite of the second stage of mineralization. Selenium content tends to increase in later stages in rhodochrosite, to decrease in later stages in sphalerite, to increase in middle stages in pyrite, to decrease in middle stages in galena. Distribution of the minor elements, including selenium, has some relation not only to the chemical character of the ore solution but also to the physical conditions at the time the minerals crystallized.

Sandals, K. M. *See* Moxon and others, 1938.

Sanderson, L., 1940, Selenium: Canadian Mining Jour., v. 61, p. 370–371.

A summary of sources, properties, extraction, and uses of selenium.

Sanford, Samuel. *See* Schrader and others, 1917.

Santmyers, R. M., 1930, Selenium and tellurium: U. S. Bur. Mines Inf. Circ. 6317, 23 p.

A summary of chemical properties, uses, identification tests, history, occurrence, minerals, preparation, production, imports, exports, markets, and prices of selenium. Tables show sales of selenium from 1910 to 1927, imports from 1913 to 1928, and monthly prices for 1913 and from 1920 to 1929.

Sarasin, Edmond. *See* Friedel and Sarasin, 1881a, b.

Sargent, J. D., 1954, Selenium: U. S. Bur. Mines Inf. Circ. 7690, 25 p.

Discussion of physical and chemical properties, geology, mineralogy, geographic distribution, domestic and foreign production and consumption, metallurgy, and uses of selenium. Appendix contains lists of selenium minerals, seleniferous formations, indicator plants, United States production and imports, and bibliography.

——— 1955a, Selenium data (Revision of Inf. Circ. 7690): U. S. Bur. Mines Inf. Circ. 7715, 29 p.

Discussion of physical and chemical properties, geology, mineralogy, geographic distribution, domestic and foreign production and consumption, metallurgy, and uses of selenium. Appendix contains tables of selenium minerals, seleniferous formations, indicator plants, United States production and imports, production of electrolytic copper refineries, and bibliography.

——— 1955b, Selenium, *in* Mineral facts and problems: U. S. Bur. Mines Bull. 556, 6 p.

A summary of geographic distribution, geology, metallurgy, reserves, uses, government wartime controls, substitutes, domestic production, consumption, foreign trade, prices, research, outlook, and problems of selenium.

Saunders, A. P., 1900, The allotropic forms of selenium: Jour. Phys. Chemistry, v. 4, no. 6, p. 423–513.

Selenium exists in three forms: (a) liquid (above 220° C.), (b) crystalline red, (c) crystalline gray or metallic. Describes properties and transformations of the different forms of selenium.

Schaller, W. T. *See* Hewett and others, 1936.

Schellinger, A. K. *See* Koeppel and Schellinger, 1957.

Scherbatoff, H. *See* Jacks and Scherbatoff, 1940.

Schloen, J. H. *See also* Clark and Schloen, 1944.

Schloen, J. H., and Elkin, E. M., 1946, Canadian Copper Refiners Montreal East plant: Canadian Inst. Mining and Metallurgy Trans., v. 49, p. 143–190.

Ore from the Noranda and Hudson Bay mines is treated at the Montreal East plant. Ore from Noranda typically contains 0.144 percent selenium, that from Hudson Bay contains 0.117 percent selenium. Selenium plant operation is described.

——— 1950, Treatment of electrolytic copper refinery slimes: Am. Inst. Mining Metall. Engineers Trans., v. 188, p. 764–777.

Analyses are given of selenium in anodes, raw slimes, and treated slimes from Boliden, Sweden; Noranda, Quebec; Electrolytic Refining and Smelting Co., Port Kembla, New South Wales, Australia; Mount Lyell, Tasmania; Norddeutsche Affinerie, Hamburg, Germany; Outokumpu, Finland; and Rhodesia Copper Refineries Ltd., N'kana, Northern Rhodesia. Methods used at the refineries are described. Bibliography on selenium metallurgy.

Schloen, J. H., and Elkin, E. M., 1954, Treatment of electrolytic copper refinery slimes, *in* Copper, by Allison Butts: New York, Am. Chem. Soc. Mon. Ser., Reinhold Pub. Corp., p. 266–269.

Article contains tables giving selenium content of copper anodes, raw slimes, and leached slimes from American Smelting and Refining Co.; Anaconda Co.; Boliden, Sweden; Montreal East and Noranda (Canadian Copper Refiners); Cerro de Pasco, Peru; Port Kembla, New South Wales; Mount Lyell, Tasmania; Copper Cliff, Ontario; Kennecott; Norddeutsche Affinerie, Hamburg, Germany; Phelps Dodge; Outokumpu, Finland; Raritan; N'kana, Rhodesia; and U. S. Metals smelters.

Schmidt, Max, 1925, Beitrag zur Bestimmung kleiner Selenmengen in sulfidischen Mineralien: Metall u. Erz, v. 22, no. 19, p. 511–512.

Sulfide minerals contained the following amounts of selenium: sphalerite from Norway, 0.0004 percent; sphalerite from Oberschlesen, Germany, 0.0002 percent; sphalerite from Harz, Germany, 0.0001 percent; galena from Spain, 0.0003 percent; bismuthinite from Schneeberg, Germany, trace; argentite from Freiberg, Germany, 0.001 percent; chalcopyrite from Butte, Mont., 0.005 percent.

Schmitt, Marg. *See* Ramdohr and Schmitt, 1955.

Schoeller, W. R., and Powell, A. R., 1920, Villamaninite, a new mineral: Mineralog. Mag., v. 19, no. 88, p. 14–18.

A new mineral from the Cármenes district near Villamanín, Province of León, Spain, has the formula, $(Cu, Ni, Co, Fe)(S, Se)_2$, and contains about 1.5 percent selenium. The ores of the district are sulfide minerals of copper, cobalt, and nickel in a dolomite gangue.

Schrader, F. C., 1923, The Jarbidge mining district, Nevada: U. S. Geol. Survey Bull. 741, p. 30.

Naumannite occurs with argentite, electrum, and gold in a gangue of quartz and adularia in veins of the Jarbidge district, Nev.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, 1917, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 78, 305, 308, 388, 399, 405.

Tiemannite occurs in large masses near Clear Lake and at the Abbott mine in Lake County; at the San Joaquin Ranch mine in Orange County; and at the Guadalupe mine near Los Gatos in Santa Clara County, Calif. Onofrite and tiemannite occur at the Lucky Boy mine near Marysvale, Utah.

Schroll, Erich. *See* Rockenbauer and Schroll, 1955, 1956.

Schumb, W. C. *See* Marvin and Schumb, 1935.

Searight, W. V. *See also* Moxon and others, 1938, 1939.

Searight, W. V., and Moxon, A. L., 1945, Selenium in glacial and associated deposits: South Dakota Agr. Expt. Sta. Tech. Bull. 5, 33 p.

Brookings, Kingsbury, Hamlin, Beadle, Day, Clark, Deuel, Grant, Spink, Brown, Codington, and Roberts Counties contain Pleistocene glacial deposits underlain by seleniferous chalk beds of the Mobridge member of the Pierre formation. Selenium occurs in small amounts in all glacial and associated deposits of northeastern South Dakota and western Minnesota. Selenium is mostly in silt and clay in Pleistocene deposits, derived from the seleniferous formations over which the glaciers moved. The greatest amount of selenium is in Arlington loess and loesslike silts in poorly drained areas where it has been leached, transported downslope, and redeposited at lower levels.

Searight, W. V., Moxon, A. L., Hilmoe, R. J., and Whitehead, E. I., 1946, Occurrence of selenium in Pleistocene deposits and their derivatives in South Dakota: Soil Sci., v. 61, no. 6, p. 455–463.

All Pleistocene glacial tills of northeastern South Dakota contain selenium, averaging less than 1.5 ppm selenium. Loess deposits contain little selenium in upland areas; in depressions they carry noteworthy amounts. The source of the selenium in glacial drift, outwash, alluvium, and loess is bedrock or older drifts over which the glaciers have moved. In South Dakota seleniferous Cretaceous formations underlie Pleistocene glacial deposits.

Searight, W. V., Moxon, A. L., Whitehead, E. I., and Viets, F. G., Jr., 1946–47, Detailed mapping of seleniferous vegetation on soils of Pierre origin: South Dakota Acad. Sci. Proc., v. 26, p. 87–98.

The stratigraphic distribution of selenium sources in the Virgin Creek, Mobridge, and Elk Butte members of the Pierre formation in northwestern Lyman County, S. Dak., was mapped by determining the selenium content of western wheatgrass growing on the soils. The selenium source beds are horizontal, so that the ranges of maximum selenium content can be mapped topographically. The authors discuss the possibility of mapping toxic areas on the basis of the topographic position of seleniferous beds.

Selvig, W. A. *See* Gibson and Selvig, 1944.

Shannon, E. V., 1920a, An occurrence of naumannite in Idaho: Am. Jour. Sci., ser. 4, v. 50, p. 390–391.

Naumannite, a selenide of silver, occurs as nodules in white to bluish clay filling fissures in silver stopes of the De Lamar mine, Silver City district, Owyhee County, Idaho. The mineral resembles argentite and it is possible that much of the silver ore mined was naumannite rather than argentite.

——— 1920b, Boulangerite, bismutoplagionite, naumannite, and a silver-bearing variety of jamesonite: U. S. Natl. Mus. Proc., v. 58, p. 589–607.

Naumannite from the De Lamar mine, Silver City district, Owyhee County, Idaho, contained 22.92 percent selenium and 1.10 percent sulfur.

——— 1925, Tetradymite from the Hailey quadrangle, Idaho: Am. Mineralogist, v. 10, p. 198–199.

Tetradymite, from near the head of Trail Creek, Hailey quadrangle, Blaine or Custer County, contains small amount of selenium replacing tellurium.

——— 1926, The minerals of Idaho: U. S. Natl. Mus. Bull. 131, p. 82, 101–104.

Selenium appears to be confined to, and characteristic of, late Tertiary veins in volcanic rocks. Guanajuatite was found on Kirtley Creek, northeast of Salmon, Lemhi County. Naumannite was found in the Montana and Lucky Boy mines, Yankee Fork district, Custer County; Monument mine, Gravel Range district, and Parker Mountain district, Lemhi County; De Lamar mine, Silver City district, Owyhee County. Clausthalite was found in the Hypotheek mine, Coeur d'Alene district, Shoshone County.

Shcherbina, V. V., 1949, Concentration and dispersion of chemical elements in the earth's surface as a result of oxidative and reductive processes: Akad. Nauk SSSR Doklady, v. 67, p. 507–510. [Russian.]

Generalized view of oxidation-reduction reactions as a means of distribution of elements is presented. Oxidations tend to concentrate salts of heavy metals, formed by the oxidation of acids of vanadium, molybdenum, chromium, arsenic, selenium, tellurium, sulfur, and phosphorous. Sulfides, selenides, and tellurides show decreased hydrolyzability on oxidation and their concentration takes place only after reduction reactions. (Chem. Abs., v. 43, col. 8996.)

Shigematsu, Tsunenobu. *See* Ishibashi and others, 1953.

Shimidzu, Tetsukichi. *See* Divers and Shimidzu, 1883.

Short, M. N., 1931, Microscopic determination of the ore minerals: U. S. Geol. Survey Bull. 825, p. 79, 80, 83, 85, 86, 93, 94, 104, 105, 167–168.

Determinative tables for selenium minerals, aguilarite, clausthalite, eucairite, klockmannite, lehrbachite, naumannite, onofrite, tiemannite, and umangite; tests for selenium.

Shutt, R. *See* Waitkins and others, 1942.

Sill, C. W., and Peterson, H. E., 1954, Iodometric determination of selenium in ores and flue dusts: U. S. Bur. Mines Rept. Inv. 5047, 9 p.

A new method is described for direct titration of selenious acid to a starch-iodide end point by adding starch to selenious acid and enough potassium iodide to form a transparent blue color, and then titrating with standard thiosulfate. This method retains the colorless end point of the Norris and Fay method and can be used for determining much larger quantities of selenium than is possible by the McNulty method. Procedures are given for precipitating metallic selenium from flue dust or ore, for oxidizing metallic selenium to selenious acid, and for titrating with thiosulfate.

Sisson, L. L. *See* Olson and others, 1940.

Slater, C. S., Holmes, R. S., and Byers, H. G., 1937, Trace elements in the soils from the erosion experiment stations, with supplementary data on other soils: U. S. Dept. Agriculture Tech. Bull. 552, 23 p.

Eleven soil profiles representing 4 of the great soil groups and 3 other soils were examined. The 11 profiles included soils from Wisconsin, Kansas, Iowa, Washington, Missouri, Texas, Ohio, Oklahoma, and North Carolina. Their selenium content ranged from 0.01 to 2.50 ppm. Pierre clay loam and Niobrara sandy clay loam contained 22 and 18 ppm selenium respectively. A relatively high selenium content was found in soils of low silica-sesquioxide ratio, and a tendency for illuviated horizons to have an accumulation of selenium was noted.

Slattery, M. K., 1925, The crystal structure of tellurium and selenium and of strontium and barium selenide: Phys. Rev., ser. 2, v. 25, p. 333–337; abs. v. 21, p. 378–379.

Selenium crystallizes in a simple triangular lattice with three atoms grouped at each corner. Strontium and barium selenide have simple cubic structures.

Smith, W., 1915, Estimation of selenium in sulphur: Indus. Eng. Chemistry, Indus. Ed., v. 7, p. 849.

The article describes a method for estimating the amount of selenium in sulfur. Four samples of commercial sulfur from Japan contained 0.045, 0.055, 0.085, and 0.152 percent selenium.

Spencer, A. C., 1917, The geology and ore deposits of Ely, Nevada: U. S. Geol. Survey Prof. Paper 96, p. 112.

Ely porphyry copper ores yielded 110 pounds of selenium for each 100 tons of blister copper refined at the Steptoe smelter.

Spurr, J. E., 1905a, Developments at Tonopah, Nevada, during 1904: U. S. Geol. Survey Bull. 260, p. 140–149.

Sulfide ore from the Montana vein, Montana Tonopah mine, contained 2.56 percent selenium; oxidized ore from the Valley View mine contained 0.78 percent selenium. Selenium occurs in part as a silver selenide; a selenide of gold is not impossible. The oxidized ore shows that much of the silver selenide is attacked by oxidizing agents. "The oxidized ore of Tonopah is really a modified ore, consisting of an intimate mixture of sulfides and selenides, together with secondary sulfides, chlorides, and oxides."

——— 1905b, Geology of the Tonapah mining district, Nevada: U. S. Geol. Survey Prof. Paper 42, p. 92–93, 281, 285.

Analysis of oxidized ore from the 300-foot level of the Valley View vein contains 0.78 percent selenium. Selenium occurs, in part at least, as a silver selenide. There is less than one third as much selenium in the oxidized ore as in the sulfide ore. The primary ores contained quartz, adularia, carbonates, polybasite or stephanite, argentite, chalcopyrite, pyrite, galena, sphalerite, silver selenide, and gold in an undetermined form.

Starrett, W. H. *See* Cannon and Starrett, 1956.

Stoklasa, Julius, 1922, Über die Einwirkung des Selens auf den Bau- und Betriebsstoffwechsel der Pflanze bei Anwesenheit der Radioaktivität der Luft und des Bodens: Biochem. Zeitschr., v. 130, p. 604–643.

Occurrence of selenium in pyrites, radioactive materials, sulfuric acid, and in certain sulfate and phosphate fertilizers is noted. Selenium is released into the air during the roasting of pyrites, smelting operations, and burning of coal. Studies of the biochemical effect of such selenium on plants and seeds in the presence and absence of radioactivity are described.

Stone, J. R., and Caron, P. E., 1954, Selenium *in* Hampel, C. A., ed., Rare Metals Handbook: New York, Reinhold Publishing Corp., p. 347–377.

General treatise containing summary of history, occurrence, methods of recovery, fabrication, toxicity, and uses of selenium. Physical and chemical properties are described in detail.

Stone, R. W. *See* Schrader and others, 1917.

Stradner, E. *See* Machatschki and Stradner, 1952.

Strock, L. W. *See also* Goldschmidt and Strock, 1935.

Strock, L. W., 1935, The distribution of selenium in nature: Am. Jour. Pharmacy, v. 107, no. 4, p. 144–157.

Summary of data from paper by Goldschmidt and Strock on the distribution of selenium in products of magmatic origin and of secondary erosion and sedimentation. The distribution of selenium in sulfides is associated with the differentiation and cooling of primary magma. Selenium is richer in the primary sulfide phase of the first differentiation of the magma, such as troilite meteorites and pneumatolytic sulfide ores. Sulfides of magmatic segregation origin contain less selenium, and hydrothermal sulfides which issue from the magma in the last stages of differentiation contain the least selenium. In the erosion cycle a very high oxidation potential is required to oxidize selenide to selenate. Selenium in a very soluble form was present in highly oxidized caliche beds in the Atacama desert, Chile. Selenium does not follow sulfur into sea water but is absorbed by ferric hydroxide-rich marine sediments, thus accounting for seleniferous sedimentary iron ores. Possible sources of selenium in shales and other sedimentary rocks are: (a) erosion of caliche and lignite beds, (b) absorption from water by ferric hydroxide and plants. Sources of selenium in soil are the parent selenium-rich sedimentary rocks, magmatic rocks with sulfide masses, eroding caliche beds, and waters, which have leached other formations, rising to the surface.

Swaine, D. J., 1955, The trace-element content of soils: Commonwealth Bur. Soil Sci. [Harpenden] Tech. Commun. 48, p. 91–99.

Tabulated information on selenium content of soils in Ireland, Russia, Japan, Canada, Mexico, Puerto Rico, Colombia, New Zealand, Hawaiian Islands, and United States—including Wyoming, Oklahoma, South Dakota, Nebraska, Montana, Colorado, Kansas, New Mexico, Arizona, North Dakota, Nevada, Texas, Missouri, Utah, New Jersey, California, and Idaho.

Sweeney, A. *See* Walsh and others, 1951.

Taber, Stephen, 1913, Geology of the gold belt in the James River Basin, Virginia: Virginia Geol. Survey Bull. 7, p. 160.

Tetradymite in gold-bearing quartz veins in quartz-sericite schist at the Tellurium mine, Fluvanna and Goochland Counties, contains traces of selenium.

Taboury, F., 1909, Sur la présence du sélénium dans les eaux minérales de La Roche-Posay, Vienne: Soc. chim. France Bull., ser. 4, v. 5, p. 865–867.

Waters from each of the 3 sources of the spring at La Roche-Posay, Vienne, France, contained 0.2 milligram per liter of selenium.

——— 1932, Sur la présence accidentelle du sélénium dans certains végétaux: Acad. sci. [Paris] Comptes rendus, v. 195, p. 171.

Of 3 species of plants growing in a seleniferous spring at La Roche-Posay, Vienne, France, 2 were found to have absorbed selenium in their tissues.

Terada, Shizuo. *See* Tsuge and Terada, 1950.

Thompson, M. E., Roach, Carl, and Braddock, William, 1956, New occurrences of native selenium: Am. Mineralogist, v. 41, nos. 1 and 2, p. 156–157.

Native selenium has been identified in three localities during studies of sandstone-type uranium-vanadium deposits. The selenium occurs as purple-gray metallic acicular crystals, usually in a felty aggregate of small crystals not more than 2 mm in length. The localities are the Road Hog No. 1A mine, Black Hills, Fall River County, S. Dak., in Lakota sandstone of Early Cretaceous age; Peanut mine, Bull Canyon, Montrose County, Colo., in high-grade ore in Salt Wash sandstone member of the Morrison formation of Late Jurassic age; and Parco No. 23 mine, Thompsons district, Grand County, Utah, in Salt Wash sandstone member of the Morrison formation.

Thompson, R. M., 1954, Naumannite from Republic, Washington: Am. Mineralogist, v. 39, p. 525.

Banded quartz from Republic, Washington, contains concentric black metallic bands consisting of argentian tetrahedrite in which small particles of gold, electrum, pyrite, chalcopyrite, and naumannite are embedded.

Thorvaldson, T., and Johnson, L. R., 1940, The selenium content of Saskatchewan wheat: Canadian Jour. Research, v. 18, sec. B, p. 138–150.

Analyses are given of 230 composite samples of wheat grown in Saskatchewan. The maximum amount of selenium found was 1.5 ppm, contained by 3.2 percent of the samples; the average amount of selenium found was 0.44 ppm. Wheat grown on soil of glacial lacustrine origin generally contained more selenium.

Trelease, H. M. *See* Trelease and Trelease, 1938.

Trelease, S. F., 1945, Selenium in soils, plants, and animals: Soil Sci., v. 60, no. 2, p. 125–131.

Selenium is present in soil as insoluble ferric selenite, soluble selenates, and organic compounds derived from plant decomposition. Selenium accumulator plants are native range plants rather than cultivated crops or native grasses. Accumulator plants are capable of absorbing selenium from virgin shale soils, converting it into water-soluble forms, and returning it to the soil in a form available for absorption by all types of plants.

Trelease, S. F., and Beath, O. A., 1949, Selenium, its geological occurrence and its biological effects in relation to botany, chemistry, agriculture, nutrition, and medicine: New York, Published by the authors, 292 p.

A general survey of selenium as it is related to agriculture and public health, containing chapters on history of selenium poisoning, selenium indicator plants, distribution in rocks and soils, accumulation of selenium by plants, selenium poisoning in animals, selenium in relation to public health, prevention and control of selenium poisoning, and chemistry. Maps show outcrops of Permian, Triassic, Jurassic, Cretaceous, and Tertiary formations and locations of plant samples containing 50 ppm or more of selenium in the Western United States. A discussion on origin of selenium in rocks and types of selenium-bearing materials is given.

Trelease, S. F., and Trelease, H. M., 1938, Selenium as a stimulating and possibly essential element for indicator plants: Am. Jour. Botany, v. 25, no. 5, p. 372–380.

Inorganic selenite used in experiments was found to be essential for growth of indicator plants. Addition of sulfur tended to reduce the intake of selenium by plants growing in environments of low selenium concentration.

Trites, A. F., Jr., 1956, Selenium occurrences in the United States: Mines Mag. [Colorado], v. 46, no. 8, p. 43–44.

Selenium occurs associated with uranium in the Gas Hills area, Fremont County, Wyo., in the Temple Mountain and Henry Mountain areas, Utah, and in the Grants area, N. Mex., where it has been released from pyrite by oxidation. Selenides of copper, lead, silver, and mercury are found in many sulfide deposits in the Western United States and Mexico. Selenium is associated with sulfur in volcanoes in Hawaii and Alaska, and at the Vulcan mine, Gunnison County, Colo. It occurs in the phosphate deposits of the northwestern States and in the Upper Cretaceous rocks of the Colorado Plateau and the Western States.

Trites, A. F., Jr., and Lakin, H. W., 1956, Behavior of selenium in the zone of oxidation: Internat. Geol. Cong., 20th, Mexico 1956, Resúmenes Trabajos Presentados, p. 377–378.

Selenium released during oxidation of seleniferous sulfide minerals is in less soluble form than sulfur and tends to be concentrated in the oxidized zone. In seleniferous pyrite-bearing sandstone-type uranium deposits of the Colorado Plateau and Wyoming, secondary selenium minerals are concentrated either in mantles overlying unoxidized ore bodies or in haloes enclosing these bodies. The most seleniferous rock is commonly sandstone containing red elemental selenium with varying amounts of hydrous iron oxide containing some basic ferric selenite. Small amounts of selenium are being removed from these deposits by surface and underground water; some of this selenium is retained in the rock as basic ferric selenite, some is absorbed in plants, some enters the atmosphere as gas, some enters streams to be discharged in the ocean and inland basins. Concentrations of selenium are now being built up in bottom sediments in the Gulf of California outward from the mouth of the Colorado River.

Truscott, S. J., 1901–02, The occurrence and mining of gold in the Dutch East Indies: Inst. Mining and Metallurgy Trans., v. 10, p. 52–57.

The Radjang Lebong gold mine in southwestern Sumatra is a reef 1,000 feet long in porphyrite or altered andesite country rock. The ore is hard, close-grained amorphous silica with very little quartz, containing in places a breccia of black silicified slate, and often accompanied by calcite. The gold is finely disseminated throughout, and occurs as free gold and as auriferous silver carrying 1 part of gold to 10 parts of silver. The gold may be associated with tellurium. An analysis of the bullion gives no tellurium, but it contains 4.35 percent selenium. Similar gold-bearing reefs occur at the Lebong Soelit mine, 5 miles west of Radjang Lebong, and at an unnamed reef 7 miles west of Lebong Soelit.

Tsuge, Toshihisa, and Terada, Shizuo, 1950, The selenium content of the pyrites and soils in Japan: Agr. Chem. Soc. Japan Jour., v. 23, no. 10, p. 421–425. [Japanese, English summary.]

Selenium content of pyrites from Japanese mines ranged from 0.2 to 39 ppm, with an average of 12.6 ppm; copper pyrites contained 4 to 39 ppm, with an average of 18.8 ppm; iron pyrites contained 3 to 7 ppm, with an average of 5 ppm; marcasite and pyrrhotite contained 0.2 to 0.7 ppm, with an average of 0.45 ppm. Pyrite slags contained 0.2 to 2.5 ppm, with an average of 0.86 ppm. Small quantities of selenium were found in Japanese soils, ranging from 0.4 to 1.2 ppm, with an average of 0.78 ppm. No correlation was found between the sulfur and selenium content of pyrites.

Turner, H. W., 1898, Notes on rocks and minerals from California; tellurium, selenium, and nickel in gold ores: Am. Jour. Sci., ser. 4, v. 5, p. 427–428.

Selenium was found in sulfide ore from a mine on the Mother Lode near Table Mountain in Tuolumne County.

Tyler, P. M., 1952, Selenium: Natl. Acad. Sci., Natl. Research Council, Rept. no. NMAB–15–M, 62 p.

The report contains a summary of the selenium supply situation in 1952, including United States requirements and production. Recommendations are made for reducing selenium consumption and expanding production. Increased domestic supplies can be obtained by increasing imports, improving metallurgical practice, and by developing new sources such as nonferrous metal smelting industries, uranium-vanadium plants, iron blast furnace flue dust, sulfuric acid plants, and selenium-bearing rocks and soils. Selenium in iron ore at Iron Mountain, Utah, is described. Uses, geochemistry, and metallurgy of selenium are outlined.

Umpleby, J. B., 1910, Geology and ore deposits of the Republic mining district: Washington Geol. Survey Bull. 1, 65 p.

Analyses of mixed specimens of high grade ore from intermediate levels of the New Republic mine, Ferry County, Wash., gave 5.26 percent selenium. Silver is partly in the form of silver selenide; 60 percent of the gold is combined with selenium, probably as a gold-silver selenide.

——— 1913a, Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, p. 55–56, 57, 79, 175.

Strong traces of selenium were detected in ore from the Monument mine at Myers Cove, Gravel Range district. This vein and possibly the similar Parker Mountain and Musgrove deposits are of a rare type of later Tertiary veins enclosed in Tertiary eruptive rocks and characterized by selenium which is found at Tonopah, Nev., and Republic, Wash. Selenium probably occurs at the Monument mine as a selenide of gold or silver. Its source is probably a blue-black mineral which occurs in scattered and bunched grains of microscopic size.

——— 1913b, Some ore deposits in northwestern Custer County, Idaho; U. S. Geol. Survey Bull. 539, p. 45–47.

Selenium was noted in post-Oligocene gold-silver ores of the Montana and Lucky Boy mines in the Yankee Fork district, Custer County. The ore is fine-grained quartz containing pyrite, gold, tetrahedrite, chalcopyrite, galena, and enargite. Blue-black specks in the ore contain selenium, gold, lead, bismuth, and copper. The ore veins are in Algonkian schists and quartzites and Miocene tuffs, latites, andesites, basalts, and rhyolites.

(U. S.) National Research Council, Materials Advisory Board, Panel on Selenium, 1956, Report on selenium and possible substitute materials for rectifiers: Natl. Acad. Sci., Natl. Research Council, Rept. MAB–111–M, 12 p., app. A–G.

Describes properties of selenium rectifiers and possible substitute materials for rectifiers. Possible sources of additional selenium are phosphate deposits in Idaho, Wyoming, Utah, and Montana; lysite tuffs in Wyoming; high-selenium uranium-vanadium ores; and pyrite-pyrrhotite ore of the United Verde mine, Jerome, Ariz., which contains 0.03 percent selenium and from which 1,131,500 pounds of selenium could be recovered annually for many years.

Vaes, J. F. *See also* Derriks and Vaes, 1956.

Vaes, J. F., 1947, Quelques sulfures de Shinkolobwe: Soc. géol. Belgique Annales, v. 70–B, p. 227–232.

In the Shinkolobwe deposit a mineral similar to vaesite but containing appreciable amounts of selenium was found accompanied by siegenite and small amounts of pyrite and molybdenite. It was called selenio-vaesite. A seleniferous variety of siegenite containing a small amount of tellurium was also found and was called selenio-siegenite.

Vakhrushev, G. V., 1940, Exploration of rare elements in Bashkiriya (southern Ural): Saratov. gos., Univ. Uchenyye zapiski, v. 15, no. 1, p. 124–146. [Russian.]

Selenium content of pyrites is presented: Sibaev, 0.012 percent; Bakyr-Uzyak, 0.012 percent; Bakyrtov, 0.013; Yulalin, 0.006 percent. (Chem. Abs., v. 35, col. 6541.)

Vaupell, C. W., 1938, Mercury deposits of Huitzuco, Guerrero, Mexico: Am. Inst. Mining Metall. Engineers Tech. Pub. 842, 14 p.

Tiemannite and onofrite, with other rare selenides and arsenides of mercury, antimony, and thallium, have been reported in specimens of Huitzuco ores, which are telethermal or epithermal blanket veins and stockworks in brecciated rocks. Geysers later reworked the original minerals and more recent deposits were formed in the extinct geyser and hot spring vents.

Viets, F. G., Jr. *See* Searight and others, 1946–47.

Vine, J. D., and Prichard, G. E., 1954, Uranium in the Poison Basin area, Carbon County, Wyoming: U. S. Geol. Survey Circ. 344, 8 p.

Uranium minerals were found in sandstone of the Browns Park formation of Miocene age in the Poison Basin area, 6 miles west of Baggs. Six ore samples analyzed for selenium contained from 12 to 80 ppm. The occurrence of uranium in the Poison Basin area coincides remarkably with an area known to be high in selenium content. The association of the two elements is probably not due to chemical combination in a specific mineral, but to a common origin. The association may be sufficiently common that prospecting for uranium may be continued in areas of high selenium content.

Vinogradov, A. P., 1945, A chemical study of the biosphere: Pedology, p. 348–354. [Russian, English summary.]

In a geochemical study of the biosphere, analyses were made of soils of the Russian plain from north to south along the 40th meridian. Minimum and maximum selenium contents were, in percentage of dry soil, below 10^{-5}. (Chem. Abs., v. 40, col. 1892.)

Vogt, J. H. L. *See* Beyschlag and others, 1914.

Vokes, F. M., 1957, The copper deposits of the Birtavarre district, Troms, northern Norway: Norges Geol. Undersökelse, no. 199, p. 146.

Sulfide ores occur as closely associated impregnations and breccia types, in zones parallel to the enclosing schists of the Ankerlia series. The chief ore minerals are pyrrhotite, chalcopyrite, sphalerite, and cubanite. Selenium is found in copper flotation concentrates in amounts of 50 and 100 grams per ton. These figures indicate that selenium follows chalcopyrite; however, the present work cannot be taken as supporting Carstens' conclusion that selenium varies sympathetically with copper content. In specially cleaned samples of ore sulfides, selenium varied from 0.0007 to 0.0014 percent. These figures do not reveal conclusive variations of selenium with either copper or sulfur. The selenium occurs substituting for sulfur in the sulfide lattices. Its presence in the ore is considered as evidence of an epigenetic origin of the deposits.

Waitkins, G. R., Bearse, A. E., and Shutt, R., 1942, Industrial utilization of selenium and tellurium: Indus. Eng. Chemistry, Indus. Ed., v. 34, p. 899–910.

A review of the uses of selenium, including alloys, rectifiers, ceramics, and chemical uses—including oxidizing agents, catalysts, fungicides, insecticides, antioxidants.

Walker, O. J., Harris, W. E., and Rossi, Michael, 1941, Selenium in soils, grains, and plants in Alberta: Canadian Jour. Research, v. 19, sec. B, p. 173–178.

Selenium content of 40 samples of soils varied from less than 0.1 to 1 ppm. The underlying strata of much of Alberta are of upper Cretaceous age, but the soil is derived mostly from glacial drift formed from other types of rock, so that the seleniferous area may be much smaller than earlier suspected. Seleniferous areas are more likely to be found in southern Alberta rather than in central Alberta.

Walsh, T. *See also* Fleming and Walsh, 1957.

Walsh, T., Fleming, G. A., O'Connor, R., and Sweeney, A., 1951, Selenium toxicity associated with an Irish soil series: Nature, v. 168, p. 881.

Low lying valley soils in a glaciated area underlain by upper Carboniferous limestone in County Limerick contain 30 to 324 ppm selenium. The soils are in an area of poor drainage and high rainfall. Formation of the soils was influenced by wash from the Yoredale beds (Avonian shales), which lie west of the affected area. These beds contain considerable deposits of iron pyrites, which may be the source of the selenium.

Ward, F. N. *See* Lovering and others, 1956.

Warren, H. N., 1888, Detection and estimation of selenium in meteoric iron: Chem. News, v. 57, p. 16.

Six specimens of meteoric iron contained quantities of selenium ranging from 0.04 to 0.23 percent.

Washington, H. S. *See* Clarke and Washington, 1924.

Weed, W. H., 1912, Geology and ore deposits of the Butte district, Montana: U. S. Geol. Survey Prof. Paper 74, p. 70–71, 79.

Copper ore mined in 1897 contained an average of 0.001 percent of tellurium and selenium; the matte contained an average of 0.01 percent of tellurium and selenium. Matte shipped from Butte smelters in 1897 contained .015, .0021, and .0042 percent tellurium and selenium. The ratio of tellurium to selenium in matte is from 1:1 to 3:1. The constant presence of gold, together with tellurium and selenium, in the blister copper produced by the smelters, suggests the probable presence of minute quantities of some gold-silver telluride.

Weeks, A. D., 1956, Mineralogy of uranium deposits, *in* Geologic investigations of radioactive deposits—Semiannual progress report for Dec. 1, 1955 to May 31, 1956: U. S. Geol. Survey TEI–620, issued by U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn., p. 123–127.

Selenium commonly substitutes for sulfur in sulfide minerals in the sandstone type uranium deposits to an extent not previously known. There is no significant difference in selenium content of sulfides, mostly pyrite and marcasite, from barren and mineralized rocks of the Morrison and Chinle formations. In Tertiary sediments, sulfides from mineralized rocks contain 60 times more selenium than sulfides from barren rocks. Selenium in Tertiary sulfides may have been introduced during uranium mineralization, while selenium in Morrison and Chinle formations may have been derived from volcanic debris deposited with the sediments. The highly seleniferous deposits contain clausthalite, eucairite, ferroselite, and cobaltian ferroselite.

Weeks, M. E., 1956, Discovery of the elements: 6th ed., Easton, Pa., Jour. Chem. Education, p. 306–319.

A history of the discovery of selenium and selenium minerals. Many localities are listed.

Weibull, M., 1885, Om selenhaltig galenobismutit från Falu grufva: Geol. fören. Stockholm Förh., v. 7, p. 657–666.

Gives analyses of lead bismuth selenides from Falun.

Wells, H. L. *See* Dana and Wells, 1890.

Wernimont, Grant, and Hopkinson, F. J., 1940, Microtitration of selenium: Indus. Eng. Chemistry, Anal. Ed., v. 12, p. 308–310.

Method for volumetric determination of small amounts of selenium.

White, R. L. *See* Keys and White, 1956.

Whitehead, E. I. *See* Olson and others, 1942b; Searight and others, 1946, 1946–47.

Williams, K. T. *See also* Byers and others, 1936, 1938; Lakin and others, 1938; Robinson, W. O. and others, 1934.

——— 1939, Selenium in soils, *in* Soils and Men: U. S. Dept. Agriculture Yearbook, 1938, p. 830–834.

Seleniferous soils develop in semiarid areas and are derived mostly from formations of Cretaceous, Permian, and Triassic age. Soils containing 1 ppm or less of selenium may produce toxic vegetation; irrigation reduces the selenium intake of vegetation.

Williams, K. T., and Byers, H. G., 1934, Occurrence of selenium in pyrites: Indus. Eng. Chemistry, Anal. Ed., v. 6, p. 296–297.

Analyses of pyrites from arid and humid areas in Western and Southeastern United States show a high concentration of selenium in pyrites. In humid areas pyrite is converted to limonitic material, and selenium and sulfur are transformed to soluble forms and are removed from the soil by leaching. In arid and semiarid areas, where there is little leaching, pyritiferous soil parent material forms a soil with high selenium and sulfur content. Analyses are given of pyrites from Nebraska, Utah, Colorado, Mississippi, Alabama, Georgia, North Carolina, Tennessee, and Virginia.

Williams, K. T., and Byers, H. G., 1935a, Occurrence of selenium in the Colorado River and some of its tributaries: Indus. Eng. Chemistry, Anal. Ed., v. 7, p. 431–432.

Waters taken from the Colorado, Gunnison, and Uncompahgre Rivers above irrigated lands contained very little selenium; waters taken below the entrance of irrigation drainage into rivers contained from 10 to 70 times as much selenium. Drainage waters from irrigated lands contained as much as 2.680 ppm selenium. The soils in this area are derived from seleniferous Mancos shale containing from 2 to 6 ppm selenium.

——— 1935b, Selenium in deep sea deposits: Indus. Eng. Chemistry, News Ed., v. 13, p. 353.

Nine deep sea samples taken in the Bering Sea off the coasts of Alaska and Siberia contained from 0.03 to 0.70 ppm selenium, with an average of 0.27 ppm selenium.

——— 1936, Selenium compounds in soils: Indus. Eng. Chemistry, Indus. Ed., v. 28, p. 912–914.

The chemical form of selenium in the soil determines the amount of selenium absorbed by vegetation. Pyrites carrying insoluble selenium are found in upper Cretaceous shales, particularly in the lower Pierre and upper Niobrara formations. Where iron is present in the soil, selenium may occur as insoluble basic ferric selenite. Water soluble selenates such as calcium selenate are formed in soils low in iron. The presence of selenates in humid soils is very unlikely. Organic matter in soils may contain water-soluble selenium compounds.

Williams, K. T., and Lakin, H. W., 1935, Determination of selenium in organic matter: Indus. Eng. Chemistry, Anal. Ed., v. 7, p. 409–410.

Describes method of determining selenium in air dried vegetation.

Williams, K. T., 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. Agriculture Tech. Bull. 702, 59 p.

Contains methods for determining selenium in coal and animal matter; survey of toxic vegetation and soils in Montana; report on toxic soil in Guanajuato Valley, Mexico, with analyses of soils and vegetation of Chihuahua, Juarez, and Torreon areas; discussion of nontoxic seleniferous soils of Hawaii and Puerto Rico; report on seleniferous areas of the Eagle Ford formation in Texas; report on selenium content of cores from the sea floor between Halifax, Nova Scotia, and Falmouth, England.

——— 1941, Selenium occurrence in certain soils in the United States, with a discussion of related topics; fifth report: U. S. Dept. Agriculture Tech. Bull. 758, 70 p.

Report contains tables showing selenium content of 1,000 samples of wheat from Colorado, Kansas, Nebraska, South Dakota, Wyoming, Montana, and North Dakota. The authors conclude that selenium is present in all wheat; maximum selenium content of wheat found was 25 ppm. The selenium content of 300 samples of corn, oats, and rye was studied. The maximum selenium content was 30 ppm in corn. Selenium content of soils, shales, and vegetation from Cretaceous areas of Alberta, Saskatchewan, and Manitoba is given. Reports on selenium in Montana soil profiles and seleniferous areas of North Dakota are also given. Report on selenium in meteorites shows that selenium content of stony meteorites is higher than that of octahedrite meteorites.

Wootton, W. O. *See* Cahen and Wootton, 1920.

Wright, F. E. *See* Hillebrand and others, 1914.

Zambonini, F., and Coniglio, L., 1925, The presence of soluble compounds of selenium and tellurium as products of the activity of Vesuvius: Annali osservatorio vesuviano (3), v. 2, p. 3–6.

A short review is given of the literature on occurrences of selenium and tellurium in volcanic products. A yellow crust at Vesuvius in 1925 consisted of opal, sulfur, chlorides and sulfates of alkali metals with iron, lead, copper, and calcium. An aqueous solution contained 1.25 percent selenium and 0.04 percent tellurium. (Chem. Abs., v. 22, p. 4418.)

Zies, E. G., 1929, The Valley of Ten Thousand Smokes; [Pt.] 1—The fumarolic incrustations and their bearing on ore deposition: Natl. Geog. Soc. Contrib. Tech. Papers, v. 1, no. 4, p. 26–27, 40–41.

Selenium is present in sulfur and arsenic pentasulfide incrustations around fumaroles. An incrustation at fumarole 135 contained 0.13 percent selenium.

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