TABLE V.—MISCELLANEOUS DETERMINATIONS, MONARDA PECTINATA.

Determination.	Flower Heads.	Leaves.	Stems.	Roots.
Pentosan	11.98	17.10	25.16	30.00
Crude Fiber				
U. S. P. X	26.96	15.32	45.74	47.03
Dutch Method	16.77	13.64	26.77	29.18
Tannin	1.23	3.11	2.87	2.39

SUMMARY AND CONCLUSIONS.

The results of preliminary examinations and standard tests for the customary plant constituents are tabulated. The Dragendorff determinations are run on the leaves, stems and flower heads of *Monarda menthæfolia* and the pentosan, crude fiber and tannin determinations are run on the parts of the plant of both *Monarda menthæfolia* and *Monarda pectinata.* The Dutch Method for the determination of crude fiber gives consistently lower results than the official U. S. P. method.

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SELENIUM DISTRIBUTION IN AND SEASONAL VARIATION OF TYPE VEGETATION OCCURRING ON SELENIFEROUS SOILS.*, [1]

BY O. A. BEATH,[2] H. F. EPPSON AND C. S. GILBERT.

In previous references (1, 2, 3) relating to the occurrence of selenium in native range plants no significant data were given as to its distribution in the plant itself nor was there offered at that time or since definite experimental evidence as to fluctuations of selenium with seasonal growth and development. This presentation, therefore, is an attempt to show that the amount of selenium in a seleniferous plant is not constant nor is its distribution in the plant uniform in any one part during a growing season. Many qualifying statements are necessary in attempting to show the quantitative assignment of selenium in the native range plants as they exist under natural conditions.

Geological Correlations.—The authors (1, 2, 3) in earlier publications have advanced experimental evidence to show that some native range plants, not necessarily generically related, absorb selenium in varying amounts when occurring upon shales and soils of a definite geological classification. These formations outcrop in many sections of the Rocky Mountain region. At the present time these include rocks of Cretaceous and Eocene ages and in addition two strata in the Chugwater formation. The latter is whole or in part of Permian or Triassic (?) age. The authors have stressed the fact that in dealing with seleniferous plants there are a few that stand out in their normal affinity for selenium. They constitute, therefore, a major group (Fig. 1) of positive selenium carriers. A seleniferous plant, for example, *Oonopsis condensata* will yield a comparatively low selenium value when collected on any member of the Benton, Mesaverde or Ferris

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geological formations. The same species taken at random on type Steele, Niobrara or Morrison shales will be uniformly higher in selenium for similar stages of growth. It has also been pointed out that there are areas within seleniferous shale complexes where the selenium content of much of the indigenous vegetation is surprisingly high.

Additional Native Seleniferous Plants.—The seleniferous native range plants of major significance occurring on the geological formations mentioned above, that absorb selenium in comparatively large amounts and apparently independently of intermediate influences were first

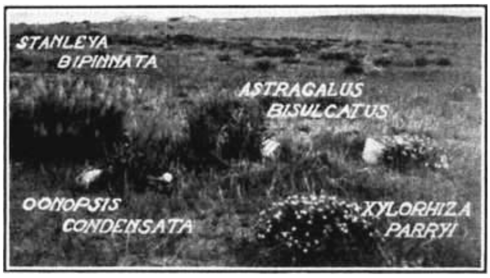

Fig. 1.—Four of the major seleniferous native range plants occurring closely associated.

reported by the authors in February 1934. It is now known that *Aster commutatis* and *Atriplex canescens* occurring on the Pierre shale consistently carry sufficient selenium at any stage of their growth to be suspicious as livestock hazards and as contaminators of the soil about them. *Aster commutatis* and *Atriplex canescens* have not been examined for selenium on any other shale than the Pierre. Other *Aster* and *Atriplex* species have not been found to consistently absorb selenium in toxic amounts from other shales and soils. In some critical toxic plant areas *A. Nuttallii* has been found to yield as high as 930 parts per million of selenium. This result was obtained from air-dried material, and consequently it is not known how much selenium was lost upon drying. On the other hand, many collections of this species have been made from normal seleniferous soils with negative or inconsequential results for selenium.

Factors Involved in Reporting Selenium in Range Vegetation.—It is apparent that a selenium value assigned to any one of the group of native range plants classified as high absorbers of selenium has limited significance unless such analyses are accompanied by the following collateral data: (1) geological formation, (2) age of plant (as indicated by size and physical character of roots), (3) green or air dried when analyzed, (4) stage of growth (early growth, flowering, seeding, etc.), (5) part of plant analyzed (root, foliage, seeds, etc.), and (6) if thrifty or stunted. That such data[1] are highly significant may be seen from the experimental evidence that follows.

(*1*) *Geological Formation*—*Astragalus racemosus* (*Tium racemosus* of Rydberg), collected at the pre-bloom stage on two types of shale gave for:

Benton shale	142 p. p. m. selenium
Niobrara shale	3140 p. p. m. selenium

Woody aster (*Xylorhiza Parryi*) collected at the pre-bloom stage of growth gave for:

Fort Union shale	13 p. p. m. selenium
Pierre shale	2300 p. p. m. selenium

[1] The quantitative results given in this paper are expressed in parts per million (p. p. m.) selenium calculated to a bone-dry basis for plants, and to air-dry basis for soils. The methods of analyses used are given in a previous publication (3), the plant material being digested by the Van Kleeck method.

The chemical analyses were made from the composited foliage of air-dried samples. The plants were grown under similar climatic conditions in eastern Wyoming. Analysis of other seleniferous plants such as are illustrated by species of *Atriplex*, *Astragali* and *Stanleya* have shown these same general trends in their selenium-soil associations.

(2) *Age of Plant.*—The size of a plant, as referred to under this heading, is interpreted as an index to the relative age of a particular species, that is, whether young, partially or wholly developed.

Astragalus bisulcatus (*Diholcos bisulcatus of Rydberg*) was selected to study the variation in the selenium content of different sized plants under the same soil conditions and similar stages of growth. Analysis of samples undried:

Foliage, past bloom for,

Moderately large plants	2920 p. p. m. selenium
Medium-sized plants	1280 p. p. m. selenium
Small-sized plants	477 p. p. m. selenium

Corresponding roots from same composites,

Moderately large roots	444 p. p. m. selenium
Medium-sized roots	172 p. p. m. selenium
Small-sized roots	75 p. p. m. selenium

While this experiment was limited to but one species, it indicates that the more mature plants, including roots, are more seleniferous than the smaller or less mature plants. In all cases the above samples represent thrifty plants.

(3) *Green or Air Dried When Analyzed.*—The loss of selenium from the time certain plants are collected until air dried may be as much as sixty-six per cent and varies with different plants, the season and stages of growth. In the spring time the green seleniferous plants that happen to grow in a field that is to be plowed up for subsequent seeding become potential contributors of available organic selenium. An analysis for selenium made upon such samples, particularly those containing volatile selenium compounds, after air drying, falls short of relating the correct interpretation of actual conditions. From the point of view of livestock poisoning the same line of reasoning pertains. If eaten at all, they are for the most part, ingested green. A correct approach to the hazards of a seleniferous range must be based upon prevailing conditions. Usually the early succulent plants show a greater selenium loss upon drying than the more mature fibrous plants. When these seleniferous range plants are thoroughly dried out, the loss of selenium is appreciably less thereafter, if the material is kept in a dry place in closed containers. Composite samples of *A. bisulcatus* at three stages of growth gave the following results:

	Green.	Air Dry.	
Pre-bloom	8840	5965	p. p. m. selenium
Full bloom	6590	3630	p. p. m. selenium
Past seeding	595	543	p. p. m. selenium

These figures show very clearly the selenium variation not only in a season's growth, but a marked loss of it during the curing process. All collections were made from the same soil environment on range plats set aside for purposes of this kind.

A composite sample of *Astragalus racemosus* collected at pre-bloom stage and analyzed green gave the following loss upon air drying:

Green.	Air Dry.	
14,920	13,900	p. p. m. selenium

A composite sample of *Xylorhiza Parryi* collected in its initial stage of growth gave the following results:

Green.	Air Dry.	
1744	1275	p. p. m. selenium

Stanleya bipinnata under similar conditions gave:

Green.	Air Dry.	
3460	1320	p. p. m. selenium

Oonopsis condensata at its early stage of growth gave:

Green.	Air Dry.	
2290	888	p. p. m. selenium

These five examples are representative of the principle native seleniferous range plants. A loss of selenium upon curing has been found to occur in every case. This loss is highly important to the analyst in arriving at the actual selenium occurrence in native range plants.

(4) *Stage of Growth.*—Some seleniferous range plants give high selenium values in their early stages of growth and then gradually decline. Others reach a maximum selenium content at later stages of development.

Woody aster samples above-ground portion, composited from the same soil environment and analyzed air dry were found to vary from 2090 p. p. m. initial growth (May) to 79 p. p. m. for past seeding plants (September).

A typical composite sample of *Astragalus pectinatus* was studied in the same manner as to its seasonal variation under the same soil and weather conditions. Plants were in the flowering stage (June) when the first sample was collected. Analyzed air-dry 1062 p. p. m. selenium were found. The next collection past seeding was made in October. Only 40 p. p. m. selenium were obtained.

Oonopsis condensata is representative of those seleniferous plants that do not reach their maximum selenium content until the flowering period as is indicated by the results that follow:

Pre-bloom—June	2290 p. p. m. selenium
Full bloom—August	4800 p. p. m. selenium
Past seeding—December	1585 p. p. m. selenium

These analyses were made on undried material and collected from the same experimental range plat.

Aster commutatis collected at four distinct stages of growth during the 1935 season from the same soil area gave the following results:

Initial growth—May	590 p. p. m. selenium
Pre-bloom—June	273 p. p. m. selenium
Full bloom—August	233 p. p. m. selenium
Seeding—November	15 p. p. m. selenium

It is apparent from these several tests that the stage of growth of a seleniferous plant is a most important adjunct in the study of selenium occurrence in range vegetation.

(5) *Part of Plant.*—The following tests were made to determine how selenium was distributed in the various parts of a typical seleniferous range plant. The first analysis was made upon *Astragalus pectinatus* at a stage of growth characterized by the fruiting period. Four divisions of the plant were made, *viz.*, green fruit, stems, leaves and roots. Analyzed green the results for selenium were as follows:

Fruits	612 p. p. m. selenium
Stems	339 p. p. m. selenium
Leaves	374 p. p. m. selenium
Roots	594 p. p. m. selenium

Fig. 2.—*Astragalus pectinatus* is deep rooted and a very consistent absorber of selenium in seleniferous shales.

From the same soil area a second collection was made of approximately one hundred pounds of *A. pectinatus* at a stage of growth when the pods were beginning to disperse their seed. The above-ground portion was separated into three divisions as follows: leaves and stems, seeds and pods. The air-dried samples were then analyzed for selenium:

Pods..........	124 p. p. m. selenium
Foliage (leaves and stems)..	260 p. p. m. selenium
Seeds.........	3250 p. p. m. selenium

Another collection of this same vetch was made in October from another soil area. At this season the foliage was considerably dried out. The main roots were included in the collection. The undried samples gave the following selenium analyses:

Foliage (leaves and stems)..	886 p. p. m. selenium
Basal roots...	5570 p. p. m. selenium

The photograph (Fig. 2) illustrates the general habitat of *A. pectinatus*.

Seeds from *A. bisulcatus* collected at a time when the foliage was mostly dried out gave 2640 p. p. m. selenium. This collection was made from the same soil area as the first collection of *A. pectinatus* referred to above.

During the late fall *A. bisulcatus* and related *Astragali*, such as *A. racemosus* and *A. scobinatulus* produce a regrowth of tender shoots that may remain green for a considerable time. Attention (3) has been called to the regrowth of certain *Astragali* and the consequences that follow if eaten by livestock. During the past fall tests were made to determine the selenium content of a representative regrowth and to compare its seleniferous character with that of the old stems and accompanying roots. (See Fig. 3.)

The samples were analyzed undried:

Results:

Old stems.....	255 p. p. m. selenium
Regrowth.....	8000 p. p. m. selenium
Roots........	800 p. p. m. selenium

The amount in the regrowth (green) compares quite closely to that found to occur in the same species at the early stages of growth in the spring of the year (8840 p. p. m.). In this connection it must be kept in mind that comparisons of this kind must be based upon similar weather conditions and seleniferous soil types.

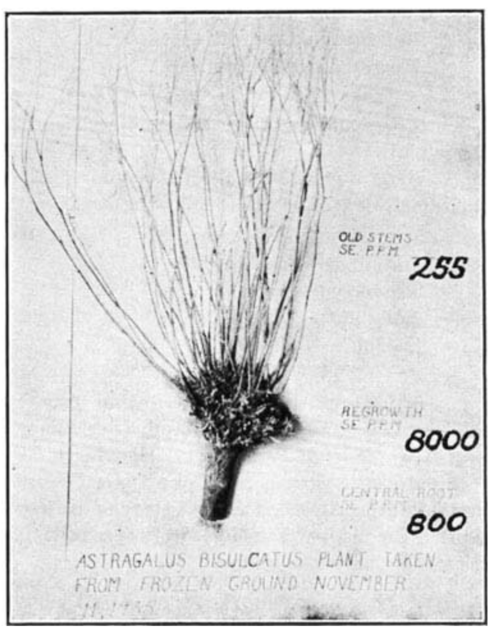

Fig. 3.—An *Astragalus bisulcatus* plant as it appears during the fall months. The regrowth is particularly attractive to grazing livestock.

The roots of *O. condensata* at the full bloom stage of growth were found to be as seleniferous as the above-ground portion for a particular composite sample collected on a type Niobrara geological shale formation. Both gave the same results, *viz.*, 4800 p. p. m. selenium. The samples were analyzed green.

From these several tests it is concluded that the total selenium in seleniferous range plants is not generally distributed uniformly throughout the entire plant structure, that the distribution of selenium in the various plant parts varies in the different species of seleniferous range plants.

(6) *Plant Thriftiness vs. Selenium Content.*—As a general rule the authors have found that a favorable growing season, initiated by an abundance of moisture, is conducive to a comparatively higher selenium absorption in plants than pertains to warm dry weather sequences. During the past four years only one growing season has been recorded that was markedly favorable to range plant development. Most of the seleniferous plants are deep rooted. Favored by an abundance of spring moisture, growth becomes vigorous and is sustained for a long time even though arid conditions prevail thereafter. The highest selenium averages in native range plants were obtained during the 1935 season which was ideal for range plant development.

Seleniferous Farm Crops.—The authors have referred, in earlier publications (2, 3) to the fact that native range plants having an avidity for selenium become activated in their poisonous properties, to a degree, quite parallel to the selenium intake. Two general types of livestock poisoning thus result, *viz.*, the acute and chronic. Both of those forms have been described in earlier references (1, 3, 5).

Fig. 4.—Seleniferous vegetation on Pierre loam being plowed under green, preparatory for the seeding of a cereal crop. The ash from burned weeds is easily discerned.

Selenium as it occurs in ordinary farm crops such as wheat, oats, barley, grasses and vegetables does not volatilize upon drying. This is in direct contrast to those seleniferous range plants that do contain highly volatile compounds of selenium. Seleniferous cereals and forages may, therefore, be cured without danger of loss of selenium. The toxic effect produced by feeding seleniferous cereals and forages to livestock is of the chronic type. Definite characteristic symptoms result which differ in many essential ways from those caused by seleniferous range weeds. The occurrence of high concentrations of selenium in certain native range plants has introduced an additional hazard apart from their effects upon grazing livestock. This hazard is one resulting in soil enrichment through the years by the decay, weathering and leaching of seleniferous range plants. The form of selenium in this group of plants is largely organic and quite completely soluble in water.

The ash remaining after burning miscellaneous seleniferous weeds may also contribute available selenium to soils. Such a condition is illustrated in Fig. 4. The dried-out weeds were burned previous to plowing. A composite ash sample gave 19 p. p. m. selenium.

Seleniferous Native Range Plants as a Source of Selenium for Farm Crops.—Referring to the photograph in Fig. 4 it will be observed that in this particular field green vegetation is being plowed under along with dried-out vegetation. The dominant green plants are *A. racemosus* and *S. bipinnata*. A composite sample of *A. racemosus* from this field, gave when analyzed green, 14,920 p. p. m. selenium. A composite sample of *S. bipinnata* likewise analyzed gave 1163 p. p. m. selenium. In 1934 wheat was grown in this field. It was highly toxic. In 1935 a crop of corn was raised. It, too, was toxic. The question could be raised at this point as to whether or not the farm crops might not have absorbed selenium quite independently of the seleniferous weeds. Reference to Fig. 5 will show that normally such absorption does not occur. The experiment, as illustrated in part, by this photograph, shows that ordinary farm crops are incapable of absorbing enough selenium from naturally occurring seleniferous shales to become toxic. In this experiment, three types of seed were sown, *A. racemosus*, *O. condensata* and *A. pectinatus*. The seedlings were all seleniferous after three months' growth. The shale used came from a Steele outcrop free from vegetation of any sort. Various farm crops grown upon this same Steele shale were found by chemical analysis to contain only traces of selenium. The purpose of this experiment is to allow these seleniferous plants to grow for several years on this shale plat with the idea that they will then have produced enough available selenium through the yearly weathering and leaching of their foliage and roots to cause vegetables, cereals etc., to become seleniferous. It is not our belief that this is the only manner in which selenium is made available to ordinary forages and crops. On the other hand, these highly seleniferous range plants cannot be excluded from consideration. Further evidence in this connection is offered by the following experiment. Raw Steele shale was mixed with an excess of coarsely cut *A. bisulcatus* (green) carrying when collected 3000 to 5000 p. p. m. selenium. A crop of wheat was grown. At the conclusion of the growing season, the following results were obtained:

Wheat heads	95 p. p. m. selenium
Stems and leaves	123 p. p. m. selenium
Roots	107 p. p. m. selenium

Fig. 5.—Illustrates two significant points: (1) that ordinary farm crops do not absorb selenium in toxic amounts from raw seleniferous shales, (2) that certain native range plants do absorb selenium from raw seleniferous shales even in the seedling stages.

A control without the addition of the vetch was found to yield a wheat crop, carrying only traces of selenium.

The same conclusive results have been obtained where the soil used was of a distinctly non-seleniferous origin.

The selenium compounds in *X. Parryi*, the *Astragali*, the *Stanleyas* and species of *Oonopsis* respond to leaching with water at room temperatures. As an illustration, a coarsely ground, air-dry sample of *X. Parryi* carrying 2090 parts per million of selenium was extracted with water at room temperature. The dregs, after two macerations, were practically free from selenium, containing only 30 parts per million.

The form in which selenium occurs in the principal seleniferous range plants is mostly organic. This conclusion is based upon the fact that freshly prepared aqueous extracts do not respond in any marked degree to the usual inorganic precipitants, namely, sulfur dioxide and hydroxylamine hydrochloride.

The roots of many of the seleniferous range plants are not only high in selenium but likewise contain water-soluble selenium compounds. Consequently, the enrichment of the soil through the decay and leaching of these highly concentrated seleniferous plants, including roots, has not only been demonstrated experimentally but has proved to be a major factor under actual farming and range conditions in Wyoming. Particular emphasis is placed upon the ease of absorption by farm crops and non-deleterious effect to them of the available selenium supplied by these native range plants.

Seleniferous Farm Crops as a Source of Selenium Enrichment.—The selenium in cereals, vegetables and forages has been found to be distributed throughout the entire plant. In some cases the roots have been found to contain more selenium than the above-ground portion. The form of selenium is known to be stable, although fifty per cent or more may be dissolved in water at room temperatures. The following tests on solubility were made from seleniferous wheat that had a selenium distribution as follows:

Grain	28 parts per million selenium
Stems and leaves	19 parts per million selenium
Roots	25 parts per million selenium

Macerating a portion of the wheat grain with water at 25° C. and the subsequent preparation of a clear aqueous extract gave upon analysis 14 parts per million of selenium. This represents one-half of the total selenium in the original wheat.

A composite sample of mature wheat plants from another source was analyzed for selenium with the following results.

Grain	35 parts per million selenium
Stems and leaves	17 parts per million selenium
Roots	36 parts per million selenium

This grain had also approximately fifty per cent water-soluble selenium. The selenium in the stems and leaves was found to be mostly soluble in water.

Wheat grown on a shale plat fertilized with green seleniferous *A. bisulcatus* was sampled when about one-half developed. The above-ground portion analyzed 300 parts per million selenium. Sixty per cent of this amount was soluble in water.

Wheat grass hay (90 bales) from eastern Wyoming was found to carry an average selenium content of 15 parts per million. This particular hay was selected because it had grown in and around the native seleniferous plants *Atriplex canescens* and *Aster commutatis*. Before being harvested it was found that samples taken from the soil in close proximity to these plants was more seleniferous (37 p. p. m.) than the samples taken outside this influence (2–5 p. p. m.). Representative composite samples were macerated with water at 25° C. and expressed. From the clarified extracts it was possible in all tests to obtain fifty per cent or more of the total selenium in the water-soluble form. In addition to this, ground hay and hay extracts were used as a source of selenium for growing wheat. A non-seleniferous soil mixed with pulverized seleniferous hay was sown to wheat. Seedling wheat plants when analyzed gave 4 p. p. m. selenium. Following this test, hay extracts were added and a second planting of wheat was made. Seedling plants contained 16 p. p. m. selenium. Hence selenium from roots, stubble and miscellaneous vegetation left in cropped fields is a potential and continuous source of available selenium for succeeding crops.

Fig. 6.—Bean plants grown in a Morrison shale with and without sulphur. Source of available selenium in soil supplied from seleniferous *Astragalus bisulcatus*.

Influence of Sulfur and Soluble Sulfates upon Selenium Absorption.—Seleniferous native range plants commonly occur on geological formations which are highly sulfated. In some instances their roots may be found embedded in gypsum seams, yet the authors have found no correlation regarding their selenium intake and sulfur or soluble sulfates.

On the other hand, it has been conclusively demonstrated that sulfur and soluble sulfates do not curtail selenium absorption by type crops when the source of available selenium is supplied through seleniferous plants typified by certain *Astragali*. In fact, the tendency is to ***increase*** the selenium intake rather than to retard it. The following experiment illustrates this point.

Selenium Content of Wheat (young plants) Grown on:

1.	Morrison shale	2 parts per million selenium
2.	Morrison shale + Vetch	227 parts per million selenium
3.	Morrison shale + Vetch + Sulfur (0.5%)	432 parts per million selenium
4.	Morrison shale + Vetch + Na_2SO_4 (0.5%)	300 parts per million selenium
5.	Morrison shale + Vetch + $MgSO_4$ (0.5%)	305 parts per million selenium
6.	Morrison shale + Vetch + $MgSO_4$ (0.4%) + Monsells salt (0.7%)	217 parts per million selenium
7.	Morrison shale + Vetch + Monsells salt (0.7%)	318 parts per million selenium

Other crops grown under similar conditions have given the same general trend in the final results.

In the experiment with beans (Fig. 6) it was found that the roots from these plants, grown in the sulfur-treated soils, gave 336 parts per million of selenium. This was more than twice the amount present in the corresponding foliage and nine times more than occurred in the foliage of the beans grown in the non-sulfur treated soil. Beans grown on Morrison shale alone gave 2 parts per million selenium. It is not believed that these results relating to selenium absorption in the presence of an excess of sulfur or soluble sulfates where the source of selenium is supplied through and by the organic forms occurring naturally in certain range plants can be ignored in evaluating the natural conditions under which seleniferous farm crops and forages are grown. In fact, there is as yet no published evidence that the application of sulfur or soluble sulfates *on a farming scale* has shown any tendency to inhibit selenium absorption by wheat or other farm crops.

SELENIUM AND CHLOROTIC VEGETATION.

Inorganic selenium compounds at certain concentrations in soils cause cereals, forages and vegetables to become stunted and chlorotic. The authors have grown wheat to maturity where 10 parts per million selenium were added to a soil as sodium selenite. No deleterious effect was noted during the development of the wheat. At the rate of 20 parts per million wheat grain germinated normally, and the subsequent growth was somewhat retarded but not chlorotic. When the selenium application was increased to 40 parts per million in the form of sodium selenite, it was found to have a decided effect upon the germination of the wheat. The plants that survived were stunted and chlorotic.

Stoklasa (4) mentioned the occurrence of discolored seleniferous plants in areas where a low grade of coal containing pyrites of iron had burned. Presumably the residual ash contained selenium as the inorganic selenites and selenates.

Of the seleniferous native range plants occurring in Wyoming, only one has been found so far that has given an abnormal reaction to cereals, grasses and vegetables when used as the source of available selenium. When this plant or water extracts from it are used, seed germination is retarded and the plants that survive are stunted and chlorotic. In addition to its selenium content, it is always a heavy carrier of molybdenum. Whether chlorosis is due to its inherent selenium or molybdenum compounds, or to the acidic character of the plant itself is not known. The plant referred to is *Oonopsis condensata*. On the natural ranges, *O. condensata* after once being firmly established completely dominates the forage cover.

Native seleniferous range plants carrying up to 15,000 p. p. m. selenium, show no chlorosis.

Organic compounds of selenium, developed by certain native range plants of the Rocky Mountain region, not only supply the soil with available selenium where these plants grow, but, in addition, their presence in excess does not cause discoloration or chlorosis. In some instances cereals and forages are greatly stimulated, but this may be due to other factors than selenium activation.

SELENIUM, NATURAL OCCURRENCE.

Elemental selenium, in a limited number of analyses, has not been found to occur to any extent in the seleniferous soils of Wyoming. As a matter of scientific interest, two experiments have been completed involving elemental selenium. In one test a non-seleniferous soil was mixed with finely powdered elemental selenium at the rate of 25 parts per million. To this was added an excess of partially decomposed horse manure, and the whole kept moist for several months. Wheat was then sown. It was cut when the wheat was about eight inches in height. Analyzed for selenium, 6.3 parts per million were obtained. It would appear that some oxidation of the selenium had taken place. The wheat plants in the control plat without the elemental selenium were non-seleniferous. The horse manure contained no selenium. This point is important, since it has been found that sheep and cattle feeding upon seleniferous feeds excrete appreciable amounts of selenium in the feces. As high as 11 parts per million selenium have been recovered from the feces of cattle that were fed seleniferous hay.

The other test on elemental selenium was as follows: A non-seleniferous soil was mixed with 25 parts per million elemental selenium and sown with seeds of *A. bisulcatus* and *A. pectinatus*. In three months' time the seedlings were seleniferous. A composite sample gave 1150 parts per million selenium. No fertilizer was used. This test demonstrates the avidity certain *Astragali* have for selenium.

Availability of Inorganic and Organic Selenium.—Concurrently with natural processes of weathering of the crude seleniferous shales as they occur in the Rocky Mountain region, it would be logical to anticipate the presence of inorganic selenium compounds and elemental selenium.

To what extent soluble inorganic selenium compounds retain their identity as such is problematical, as is indicated in the test given below. A humus soil was mixed with a solution of potassium selenite so that the resulting mixture contained 10 p. p. m. as selenium. A crop of seleniferous wheat was grown. The crop, including roots, was removed after the wheat had matured. Composite soil samples were taken and analyzed for total selenium. The results were as follows:

Inches.	Parts per Million Selenium.
0– 6	18.7
6–12	4.5
12–18	1.3
18–24	0.9

The first six inches of soil was found to contain four times as much selenium as the second six inches.

A composite was next made up by mixing samples taken from the surface foot of soil and then leaching thoroughly with water. The soil extract was then analyzed for selenium. Only 0.26 of a part per million selenium was obtained. The leached soil was then distilled with *HBr-Br* to remove the remaining selenium. However, for its complete removal digestion with nitric acid was necessary. While this is but one test, yet it is in agreement with observations made in connection with other natural soil profiles in indicating that a pronounced change takes place in the solubility of inorganic selenium compounds in certain soils. Either there are chemical changes involved or colloidal retention phenomena.

In the experimental work carried on by the authors over several years on the availability of selenium to farm crops it was observed in a general way, that of the two forms of selenium, *viz.*, inorganic and organic, a considerable variation occurred in their relative absorption by cereals when comparable quantities of the two forms were present in soils. In order to acquire specific data on this relationship the following experiments were made. Two plats were prepared in one of which was placed a mixture of Steele shale and green chopped seleniferous *A. bisulcatus* in the top foot of soil. In the other there was used for the upper foot a mixture of non-seleniferous loam and a sufficient quantity of a solution of potassium selenite so that the concentration was approximately 10 p. p. m. as selenium. Wheat was planted in both these plats and when mature was pulled up and analyzed for selenium. The results were:

	A. Bisulcatus Plat.	Potassium Selenite Plat.
Roots.........	107 p. p. m.	36 p. p. m.
Stalks.........	123 p. p. m.	17 p. p. m.
Heads.........	95 p. p. m.	19 p. p. m.

Composite samples of the soils from these plats were also taken. The total selenium content as determined by digestion and distillation with hydrobromic acid and bromine followed by nitric acid treatment was as follows:

	A. Bisulcatus Plat.	Potassium Selenite Plat.
0″– 6″.........	7.1 p. p. m.	18.7 p. p. m.
6″–12″.........	8.0 p. p. m.	4.5 p. p. m.

The results support the general observations made in connection with the availability of selenium to farm crops that the organic form of selenium is more readily absorbed than the inorganic.

Reference has been made to the seleniferous vegetation occurring in Germany on soils associated with burned lignitic coal residues. In Wyoming there are extensive areas of burned, low-grade, lignite coal seams occurring in the Fort Union geological formations. A typical unburned lignite vein in this formation gave 10 parts per million selenium. Many collections of vegetation have been made from the Fort Union "clinker beds," but in most instances no selenium has been detected. The selenium content of *A. bisulcatus* has been found to be practically the same, whether growing on the burned or unburned Fort Union shales. The conditions mentioned by Stoklasa (4) do not seem to carry the same interpretations for burned over low-grade ferruginous lignite in Wyoming.

Form of Selenium Compounds Occurring in Highly Toxic Areas.—Reference (3) has been made to several limited areas in Wyoming that carry a vegetative cover of abnormally high selenium values. The observer inspecting one of these areas would not detect any marked change in the continuity of the geological formations, or note any perceptible change in the character of the vegetation.

A type area in south central Wyoming was selected to determine the forms of selenium occurring in a soil profile. Because of the uneven topography involved, no attempt was made to sample the entire area. The point chosen was about the center of the poison area on the side of a cut bank. In the following table the analyses represent the total selenium found at one-foot intervals to a depth of seven feet.

1st foot	1.40 parts per million selenium
2nd foot	1.08 parts per million selenium
3rd foot	2.64 parts per million selenium
4th foot	6.40 parts per million selenium
5th foot	17.80 parts per million selenium
6th foot	4.70 parts per million selenium

The high selenium concentration at the fifth foot is significant in that 13.9 parts per million selenium were soluble in water. Examined further it was found that 65 per cent or 9 parts per million was inorganic selenium and the remainder organic selenium. This is the largest proportion of water-soluble selenium compounds the authors have found in any seleniferous area so far examined.

The origin of these highly seleniferous areas is problematical. Two of the worst offenders occur on the Wasatch geological formation. One interpretation advanced by the authors is that these enriched beds are residuals due to the leaching of seleniferous vegetation that may have been present during Wasatch time. Its preservation may have been aided by the impervious overlying compact shales. The other suggestion as to origin advanced by the authors is that these enrichments may have developed more recently, in fact, may be operative at the present time by the gradual accumulation of selenium from decayed vegetation, weathering processes and bacterial activity.

CONCLUSIONS.

1. A quantitative selenium assignment for a seleniferous range plant requires not only a knowledge of range associations but specific information regarding the plant itself.
2. Selenium compounds in seleniferous range plants are dominantly organic.
3. Selenium in native seleniferous range plants is readily soluble in water at room temperatures. In this form it is available to and definitely absorbed by farm crops and forages. Even when applied in relatively large amounts such crops are non-chlorotic.
4. Sulphur and soluble sulfates in the presence of organic selenium derived from native range plants and illustrated by *A. bisulcatus* have been found *not* to inhibit selenium absorption by type cereals and other farm crops.
5. In several type seleniferous farm crops the combined selenium was found to be partially soluble in water at room temperatures. In most cases more than fifty per cent could thus be isolated in hay, cereals, straw and vegetables.
6. Aqueous extracts from seleniferous hay were, when added to a non-seleniferous soil, capable of supplying growing wheat plants with available selenium.
7. Cattle and sheep excrete appreciable quantities of selenium in the feces when fed seleniferous hay.
8. Elemental selenium added to a non-seleniferous soil resulted in seedling *A. bisulcatus* and *A. pectinatus* plants becoming seleniferous (1150 p. p. m.) in three months' time.
9. The solubility of an inorganic selenite salt was found to be greatly altered when applied to a soil.
10. Soil samples from a soil profile in a critical seleniferous poison area were studied in detail and data submitted relative to the form and distribution of selenium *in situ*.
11. The roots of certain native range plants were found in some instances to carry more selenium than the corresponding above-ground portion.
12. The roots of seleniferous cereals and vegetables, in the cases examined, were found to be distinctly seleniferous.

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