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Gold Content of Water, Plants, and Animals

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By Robert S. Jones

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WALTER J. HICKEL, *Secretary*

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By ROBERT S. JONES

ABSTRACT

Sea water contains from 0.001 to 44 ppb (parts per billion) gold. The amounts of gold in fresh surface waters and ground waters are also within this range. The average amount of gold in sea water as calculated from neutron activation analyses is 0.05 ppb.

The maximum amount of gold detected in plant ash by neutron activation methods is 36 ppm (parts per million) and the average is about 7 ppm. This average, if correct, greatly exceeds the average concentration of gold in the earth's crust.

The gold content of dry matter in animals as determined by neutron activation methods ranges from 0.0012 to 430 ppb. On the basis of scanty analyses, terrestrial plants and animals appear to contain more gold than marine plants and animals.

INTRODUCTION

This report on the gold content of water, plants, and animals is one of four that summarizes available data on the occurrence of gold. The other reports are on gold in the earth's crust, in rocks, and in minerals (Jones, 1968, 1969; Jones and Fleischer, 1969). They have been prepared as background material for the Heavy Metals program of the U.S. Geological Survey, an intensified program of research on new sources of heavy metals, including gold.

Data on the gold content of ocean waters and of fresh waters, as well as on the gold content of various plants and animals, are summarized and collated. Conclusions drawn from the data must be tentative because of lack of standardization among analytical techniques.

GOLD CONTENT OF WATER

The concentration of gold in the hydrosphere is not likely to exceed 0.01 ppb (part per billion), according to Zvyagintzev (1941), but this amount seems to be nearer an average value than an upper limit. It is appreciably lower than the range from 1 to 6 ppb given as the average gold content of the earth's crust (Jones, 1968).

SEA WATER

Sonstadt (1872) was the first to make analyses of sea water for gold and gave three methods for doing so, but he obtained evidence of gold in sea water by only one of them. Since then man has dreamed of economically extracting gold from sea water. Probably the foremost of the analysts was Haber (1927, 1928) who devoted many months of research to this problem, only to foresake it when he realized from the analyses of a large number of samples of sea water that its gold content was very much less than had been previously reported. The amount of gold per cubic meter of sea water is minute and, according to Haber (1928), as based on the analyses of 1,635 samples taken at 186 stations across the South Atlantic Ocean (table 1), is 0.004 ppb. The amount of gold in sea water is estimated to be 27.4 million tons (Friedensburg, 1953).

The analyses of gold in sea water are given in table 1. Analyses made prior to 1927 are not included, but those who wish to refer to these can consult the works of Sondstadt (1872), Pack (1898), Liversidge (1897), Don (1898), Wagoner (1901), DeWilde (1905), and Koch (1918).

The seas and oceans contain varying concentrations of gold. For instance, the South Atlantic Ocean has been considered by Haber to be gold poor when compared to the amount in the other seas and oceans. Haber found at least ten times more gold for a given volume of water in the North Atlantic Ocean than he did in the South Atlantic Ocean. Other workers have also found a higher average amount (table 1). Not only do the oceans

TABLE 1.—*Gold content of seas*

Sea	Gold content (ppb)		Sampling locality	Reference	Remarks
	Range	Average			
Atlantic		<1	Brittany coast off Porspodere	Gourevitch (1933).	
Do		1	d'Ouessant Island	do	
Do		2.25	Lat 49°22′ N.; long 3°40′ W	Haber (1927).	
Do		4.1	Lat 49°22′ N.; long 15°10′ W	do	
Do		.008	Gullmarfjord	Noddack and Noddack (1939).	Method of analysis: preconcentration, spectrographic. Sample taken in shallow water.
Do	0.015–0.508	.139	British coast near Portland	Hummel (1957)	Method of analyses: neutron activation on untreated water. Sampling depths from surface to 50 m. 29 samples.
Do	.010– .021	.015	Northwest limit of Bay of Biscay at lat 46°30′ N.; long 8°00′ W.	do	Method of analyses: neutron activation on untreated water. Sampling depths from surface to approximately 600 m. 3 samples.
Do		.25	2 km from Funchal, Madeira Islands	Glazunov (1929).	
Do		.004	Between Africa and South America	Haber (1928)	During the cruise of the "Meteor," 1,635 samples were taken.
Do	.001– .044	.008	Along lat 42° S	Haber (1927)	36 samples.
Do	2.88 –8.46	5.79	Near Newfoundland Banks	do	5 samples.
Arctic	.016– .128	.04	Lat 73°36′ to 74°52′ N.; long 12°26′ to 20°00′ W.	do	
Do	.009– .186	.047	Lat 61°19′ to 66°53′ N.; long 4°43′ to 24°31′ W	do	
Do	.498–4.843	2.07	do	do	3 analyses. Melt water of surface ice.
Mediterranean	.21 –1.9		Between Gibraltar and Lisbon	Stark (1943)	Method of analyses: fire assay and micrographic.
Do	.31 – .94	.4	Between Gibraltar and Genoa	do	Do.
Do	.05 –1.51		Coast of Corsica	do	Do.
Do	.21 – .61		Monaco Coast	do	Do.
Adriatic	.009– .020	.02	Coast between Venice and Fiume	do	Do.
Pacific	.003– .029	.01	San Francisco Bay near Sausalito	Haber (1927).	
Do	.002– .055	.015	San Francisco Bay near Oakland (jetty)	do	
Do	<.1		15 nautical miles off California coast	Claude (1936)	Position along coast not given. A number of samples were probably taken along the coast and about 15 miles out.
Do		.068	40 miles west of San Francisco	Weiss and Lai (1963).	Method of analysis: organic coprecipitation, colorimetric checked with radioactive tracers.
Do	Trace– .25	.08 (about)	Washington coast (Puget Sound)	Caldwell (1938)	Depth 180 m.
Do	.375, 1	.69	Washington coast (Strait of San Juan de Fuca).	do	
Do	5.1, 44	24.5	Washington coast (Copalis Beach and Mutiny Bay).	Putnam (1953)	Method of analysis: electrolysis.
Do	.175– .30	.23	Oregon coast (Waconda Beach)	Caldwell (1938).	
Do		3	Japanese coast (Tokyo Bay)	Yasuda (1927, 1928).	
Do		10	Japanese coast (Kominato Bay)	do	
Do		20	Japanese coast (Kagoshima Bay)	do	
Do	.006– .429		Japanese coast (East of Honshu Island)	Oka, Kato, and Sasaki (1964).	Method of analysis: neutron activation. 7 samples taken from depths of 100 to 200 m, and 14 surface samples.

and seas vary in the amount of gold that they contain, but so do samples taken simultaneously "side by side" (Hummel, 1957).

Haber (1927), probably hoping to find larger amounts of gold in sea water near goldfields, analyzed more than 100 samples of sea water from San Francisco Bay, just off Sausalito and Oakland. The waters near Oakland contained as much as 0.055 ppb and had a median value of 0.012 ppb gold. The time of day that the samples were taken and the ebb and flow of the tide seemed to be insignificant factors in the amount of gold found in the analyzed sea water. Farther from shore, 40 miles west of San Francisco, the ocean water contained 0.068 ppb gold (Weiss and Lai, 1963).

Hummel (1957) found 0.015 to 0.5 ppb gold in sea water; Caldwell (1938), Stark (1943), and Putnam (1953) obtained values of from 0.02 to 44 ppb (table 1). Caldwell (1938) concluded that there is a maximum of about 0.1 to 0.2 ppb gold in the sea water off the Oregon coast or in Puget Sound (Washington). However, these figures might be low considering the values given by Putnam. Stark noted that samples of water from the Adriatic Sea contained an average of 0.02 ppb gold and from the Mediterranean Sea, 0.4 ppb. The maximum amount of gold in sea water obtained off the Iberian coast was almost 2 ppb.

Sea water off the coast of eastern Japan has been taken from various depths and analyzed for gold by the neutron flux method (Oka, Kato, and Sasaki, 1964). The amount of gold found ranged from 0.006 to 0.429 ppb. The content varied in different places, but the amount of gold in deeper waters was somewhat less than that found in surface waters. Where cold and relatively warm waters mingled, such as the cold Kuril current (Oya Shio) with the warmer Black current (Kuro Shio) (Zenkevitch, 1963), the gold content was relatively high. Analyses from other places near the Japanese coast indicated the gold content of sea water ranged from 3 to 20 ppb (Gmelin, 1954, p. 125–130).

In one locality, during a spring bloom of phytoplankton, a decrease of about 15 percent in dissolved silicate contents occurred, and the gold contents decreased 60 percent (Hummel, 1957).

Peshchevitskii, Anoshin, and Erenburg (1965) believe that gold in sea water is present mostly in the form of the complex anion ($AuCl_2^-$), although this was contrary to Haber's (1928) conclusion that gold was associated with particulate matter. Schutz and Turekian (1965) question Haber's conclusion stating: "The precision of his (Haber's) determination of four centrifuged samples was no better than on the original water, so the association of gold with particulate matter does not seem to be the primary contribution to analytical variance in his method."

Hummel (1957), though, believes that gold concentration tends to decrease away from shore and agrees with Haber that the gold is associated with particulate matter because of the inconsistent variability of gold content with depth from the surface of the water downward and also the decrease in the gold contents as samples are obtained progressively farther from shore.

FRESH SURFACE WATER

River waters have been considered as being too low in gold content to make them worthwhile as a tool for geochemical prospecting for gold in gold-bearing regions (Konovalov, 1941), although Kropachev (1935) considers values of 0.06 ppb and more gold in water as being useful for prospecting purposes. In the rivers of the Irkutsk region and Transbaikal, the gold values are mostly from 0.01 to 0.09 ppb, in the Krestovka 0.016 ppb, the Zarca 0.33 ppb, the Unda 1.7 ppb, the Gazimur 4.7 ppb, and water from Lake Baikal at the mouth of the Krestovka River 0.12 ppb (Kropachev, 1935). Samples of water from the Sutar River contained 0.005 to 0.01 ppb of gold and averaged 0.03 ppb (Konovalov, 1941). Rhine River waters near Karlsruhe averaged 0.0039 ppb gold, near Leverkusen 0.0027 ppb of gold, and near Schöpfstellen, 0.003 ppb gold (Haber and Jaenicke, 1925). Fischer (1966) found 2 ppb gold in unfiltered Saale River water and 0.1 ppm (part per million) gold in the suspended matter.

GROUND WATER

Thermal waters rising from great depths are known to contain gold. The gold content in the deep waters of the Comstock Lode, whose temperatures vary from 116° to 170°F, is 0.298 ppb (Lincoln, 1911). Vadose water at the Comstock Lode contains both gold and silver in solution.

Studies of gold in hot springs of Beppu (Japan) were made by Koga (1960, 1961). The average gold content of 27 springs was 0.53 ppb, ranging from 0.5 to 2.2 ppb gold. At the Motoyu spring at Nasu (Japan) is deposited a yellow precipitate which contained 1 to 10 ppm gold (Ikeda, 1955b). The gold content of some acid spring waters is less than 0.01 ppb (Ikeda, 1955a).

At Lake Taupo, New Zealand, sinter deposited by existing hot springs yielded 0.94 ppm gold. Maclaren (1906) noted that some siliceous sinter from Whakarewarewa south of Rotorua, New Zealand, contained about 1 ppm gold, whereas a nearby sulfurous sinter contained about 2 ppm. Grange (1937) reported 2 ppm gold and 120 ppm silver in the sinter from Whakarewarewa. The metal content of precipitates in some hot springs and boreholes in New Zealand ranged from <1 to 85 ppm gold and from <5 to 500 ppm silver (Weissberg, 1969). One of these springs, the Champagne Pool at Waiotapu, whose source is possibly as deep as 1.5 to 3 kilometers, has an areal extent of 7,000 square meters, a surface temperature of 70° to 75° C, and a pH ranging from 4.9 to 6.5. Samples of its sinter contained 80 ppm gold and 175 ppm silver. The gold content of the hot waters from another spring was ≤ 0.04 ppb and from one borehole was 0.04 ppb. Analyses of sinter from Steamboat Springs, Nev., have been reported as 1 ppm gold (Becker, 1888) and as 10 ppm gold and 400 ppm silver (White, 1967). At Boulder, Mont., a vein filling deposited by an existing hot spring contained 0.768 ppm gold; at Anaconda, Mont., the gold content of a ferruginous tufa deposited by an existing hot spring varied from 0.83 to 2.49 ppm; and at Ojo Caliente, N. Mex., a calcareous tufa deposited by an existing hot spring yielded 0.042 ppm gold (Lincoln, 1911). A water sample from the Great Salt Lake contained an equivalent of 0.032 ppm gold (Lincoln, 1911). Because some of the foregoing analyses were made before about 1928, prior to the development of modern analytical techniques for gold, it is possible that some of them may be inaccurate (Coates, 1939).

Waters flowing through mines in the Aldan Shield of the southern Yakut, U.S.S.R., contained an average of 0.7 ppb gold, and stagnant mine water contained 0.9 ppb gold (Razin and Rozhkov, 1963). In other ground waters the minimum amount of gold as determined by Landstrom and Wenner (1965), using neutron-activation method of analysis, was 0.001 ppb.

SUMMARY

The amount of gold found dissolved in sea water ranges from 0.001 to 44 ppb. The amount of gold commonly found in ground waters and river waters is also within this range. The amount of gold in sea water, as determined by neutron-activation methods, averaged about 0.05 ppb in contrast to the 0.004 ppb reported in the older work of Haber (1928) and appears to be highest near the continents and lowest in the deep ocean. A few analyses of spring waters show that the gold ranges from 0.01 to 2.2 ppb and averages about 0.5 ppb. Other ground waters contained from 0.001 to 0.9 ppb gold. River waters contained from 0.003 to 4.7 ppb gold. Zvyagintzev (1941) has stated that the amount of gold in the hydrosphere is not likely to exceed 0.01 ppb. In view of the foregoing values this is low.

GOLD CONTENT OF PLANTS

One of the oldest references to the occurrence of gold in plants was by Malte-Brun (1847) who referred to the work of Sage, Berthollet, Rouelle, Darcet, and Deyeux. Berthollet was reported to have extracted about 44 ppm gold from the ashes of vegetables.

Zvyagintzev (1941) thought that plant-root secretions and humic acids should definitely act as solvents for gold, and that this solubilization is the first process leading to the uptake of gold in plants. After the death of the plants, metals are retained in the humus (Malyuga, 1964; Curtin and others, 1968). Deul (1958) found gold in the ash of the humic acid fractions of peat. He did not detect it in plant ashes, in the whole peat ash, or in any other fraction that he separated from the peat. In seven samples Deul obtained from 1 to 10 ppm gold in the ash of the humic acid extract. Bouska, Havlena, and Sulcek (1963) in their observations on coal concluded that gold is bound predominantly, although not exclusively, to the organic part of coal.

The gold content of plants is given in table 2. The amount of gold is reported in the plant ash or in the dry plant. Also given are the ash contents of many of these plants and the amount of gold found in the soil near the plant. The values for gold in soil given by Razin and Rozhkov (1966) are the maximum values found and usually are of the C horizon of the soil. The nonvascular plants have been divided into algae, fungi, lichens, and mosses and the vascular plants into herbs (grasses and sedges, and forbs), shrubs, and trees. Most analyses given in table 2 are of vascular plants.

Some workers have noted that plants have a higher metal content at certain times of the year. Malyuga (1964) commented that toward autumn the leaves of trees have two to three times as much nickel, cobalt, and copper as they have during the spring. By contrast, Aripova and Talipov (1966) reported that the ash of wormwood (*Artemisia*) contained from 10 to 20 times more gold, copper, lead, and chromium in May than in October and that these metals are especially accumulated in plants in desert regions.

ALGAE

The ash of several marine algae have been analyzed for gold (table 2). Stark (1943) found 1.7 ppm gold in the ash of unspecified seaweeds from an unspecified locality. By contrast, Fukai and Meinke (1962) using activation methods of analysis, reported 0.00015 and 0.00093 ppm gold in the ash of two samples of sea lettuce, *Ulva* sp. In the dry matter of these samples, one from Tokyo Bay, Japan and the other from Sagamu Bay, Japan, the amount of gold in one sample was 0.000035 ppm and, in the other, 0.00021 ppm. It is notable that these values are within the range of 0.000006 ppm to 0.000429 ppm gold found in sea water (table 1) east of Honshu Island, Japan by Oka, Kato, and Sasaki (1964) who also used neutron-activation methods of analysis. Because of this, and the fact that the gold in the ash of the two plants is about one order of magnitude less than the amount of gold given for the earth's crust (Jones, 1968), sea lettuce does not appear to be an accumulator of gold.

FUNGI

Fungi are known to contain from trace amounts to 11.6 ppm gold in their ash. Those containing 1 ppm or more are all *Boletus*.

LICHENS

The ashes of three lichens, *Cladonia alpestris*, *Cladonia gracilis*, and *Peltigera aphthosa* averaged 1.0, 1.3, and 1.0 ppm gold, respectively. The amount of gold in the ashes of these plants averages twice the amount of that in the soil.

MOSSES

Although Shacklette (1965) found no gold in an unspecified number of liverworts and mosses, Razin and Rozhkov (1966) recorded from 0 to 19.2 ppm gold in the ashes of mosses which they analyzed. No gold was detected in *Sphagnum fimbriatum* and a sample of *Aulacomnium palustre*. In table 2 the maximum amount of gold reported

TABLE 2.—*Gold content of plants*

[Some results were reported as 0 ppm gold; however, gold was probably present but not in sufficient amount for detection. In remarks column, number in parentheses is the amount of gold, in parts per million, in the soil near the plant]

Organism	Content in ash (ppm)	Sampling locality	Reference	Remarks
NONVASCULAR PLANTS				
Algae				
"Seaweed"	1.7		Stark (1943)	In dry material, 0.17 ppm.
Ulva sp. (sea lettuce)	.00093	Sagamu Bay, Japan	Fukai and Meinke (1962)	In dry matter, 0.00021 ppm.
Do	.00015	Urayasa, Tokyo Bay, Japan.	do	In dry matter, 0.000035 ppm.
Fungi				
Boletus bulbosus	11.6	Oslany, Czechoslovakia	Babička (1943)	Ash, 6.79 percent.
Boletus edulis	1.0	do	do	Ash, 6.51 percent.
Boletus luteus	1.0	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Ash, 1.15 percent.
Boletus rufus	1.3	do	do	Ash, 0.4 percent.
Do	Trace	Oslany, Czechoslovakia	Babička (1943)	
Boletus scaber	do	do	do	
Boletus variegatus	1.7	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Ash, 0.60 percent.
Morchella conica	Trace	Oslany, Czechoslovakia	Babička (1943)	
Polyporus fomentarius	do	do	do	
Lichens				
Cladonia alpestris (L.) Raben. (reindeer lichen).	1.0	Yakut, U.S.S.R	Razin and Rozhkov (1966).	2 samples of entire plant. Au in ppm, 0.7 and ash, 4.75 and 0.80 percent, respectively. (0.5).
Cladonia gracilis (L.) Willd. (reindeer lichen).	1.3	do	do	Entire plant with an ash content of 1.65 percent. (0.2).
Peltigera aphthosa (L.) Hoffm. (dog lichen).	1.0	do	do	2 samples of entire plant. Au in ppm, 0.6 and 1.3; ash, 0.80 and 1.02 percent, respectively. (0.5).
Mosses				
Aulacomnium palustre (Hedw.) Schwaegr.	0-10.7	Yakut, U.S.S.R	Razin and Rozhkov (1966).	7 samples of the entire plant. Ash, 0.46-10.76 percent. (4.5).
Camptothecium nitens (Schreb.) Schpr.	10.7	do	do	Entire plant with an ash content of 0.50 percent. (1.7).
Drepanocladus sp	19.2	do	do	Ash, 3.10 percent. (1.7).
Polytrichum hyperboreum R. Br. (haircap moss).	.3	do	do	Ash, 1.09 percent. (0.5).
Sphagnum fimbriatum Wilson (sphagnum).	0	do	do	Ash, 0.66 percent. (Trace [1]).
VASCULAR PLANTS				
Herbs—Grasses and sedges				
Agrostis alba L. (Redtop bentgrass)	.005	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Stems, leaves, and fruit. Ash, 1.76 percent (0.2).
Agrostis trinii Turc 3	.003	do	do	Entire plant. Ash, 41.93 percent (probably in error). (0.4).
Calamagrostis langsdorffii (Link) Trin. (bluejoint grass).	.1-1.0	do	do	9 samples of entire plant. Ash, in percent, 1.33-6.50, average, 3.39. (4.5).
Calamagrostis lapponica (Wahl.) Hartm.	0-8.6	do	do	14 samples. 11 samples of entire plant with Au in ppm, 0-0.4; ash, in percent, 1.49-5.54, average, 3.2. 3 samples of entire plant except roots. Au in ppm, 0.02-8.6; ash, in percent, 0.63-1.8, average, 1.1. (8.0).
Carex sp. (sedge)	.006-.8	do	do	2 samples of leaves, stems, and fruit. Ash, 3.79 percent in sample containing 0.006 ppm Au. (0.5).
Carex pediformis C.A.M	.06-2.4	do	do	3 samples of entire plant. Ash, in percent, 17.53, determined on 1 sample containing 0.9 ppm Au. (2.5).
Carex vanheurkii Muell	.003	do	do	Ash content of entire plant, 17.17 percent. (0.2).
Hordeum brevisubulatum (Trin.) Link (barley).	1	do	do	Stem and leaves. Ash, 2.32 percent. (0.2).
Herbs—Forbs				
Zea mays (corn)	1.5-2.0	Oslany, Czechoslovakia	Babička (1943)	3 samples.
Achillea millefolium L. (common yarrow).	0	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Ash, 2.0 percent. (0.2).
Antennaria dioica (L.) Gaertn. (common pussytoes).	1.0	do	do	Entire plant. Ash, 12.0 percent. (1.0).
Anthriscus silvestris (chervil)	4.36	Oslany, Czechoslovakia	Babička, (1943)	
Arctous erythrocarpa Small. (redfruit ptarmiganberry).	.05	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Entire plant. Ash, 0.8 percent. (0.5).
Artemisia vulgaris L. sensu lat. (mugwort).	.003	do	do	Entire plant. Ash, 5.47 percent. (0.2).
Asarum europaeum (wild ginger)	10	Oslany, Czechoslovakia	Babička (1943)	
Atragene ochotensis Pall. (clematis)	1.0	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Entire plant except roots. Ash, 2.62 percent. (4.5).
Chamaenerion angustifolium (L.) Scop. (fireweed).	0-5	do	do	Also known as *Epilobium angustifolium* L. 15 samples. 13 samples of entire plant have an Au content of 0-0.3 ppm and an ash content of 0.87-5.53 percent, which averages 2.4 percent. 2 samples of entire plant except roots contain 5.0 and 4.6 ppm Au and 0.24 and 0.31 percent ash, respectively. (8.0).
Corydalis paeoniifolia (Steph.) Pers. (fumitory).	3.3	do	do	2 samples. Entire plant except roots. Ash, 1.0 percent. (3.0).
Cryptodiscus didymus	1.5	Kyzyl-Kum, U.S.S.R	Khotamov, Lobanov, and Kist (1966).	From a dry plant with an ash content of 7.5 percent. For air-dried weight, the Au content, in ppm, is: seeds, 0.05; seed pods, 0.05; stems, 0.1; and roots, 0.05. Analyses by neutron activation. (0.2 ppm or less).

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TABLE 2.—*Gold content of plants*—Continued

Organism	Content in ash (ppm)	Sampling locality	Reference	Remarks
VASCULAR PLANTS—Continued				
Herbs—Forbs—Continued				
Datura stramonium (Jimson weed)	20.2	Gross Schüttinsel, Czechoslovakia.	Babička (1943)	Ash, 2.34 percent. (0.6).
Equisetum sp. (horsetail)	.34	North Fork of Watson Bar Creek, British Columbia, Canada.	Warren and Delavault (1950).	Ash, 16.70 percent. Plant was sampled from an auriferous area with an overburden of 4-8 ft.
Do	.17	do	do	Ash, 17.20 percent. Plant sampled from an auriferous area with an overburden of 4-8 ft.
Equisetum sp	.34	do	do	Ash, 18.00 percent. Plant sampled from an auriferous area with an overburden of 4-8 ft.
Do	.33	do	do	Ash, 22.75 percent. Plant sampled from an auriferous area with an overburden of 4-8 ft.
Do	.2	Santa Fe Creek, Santa Fe County, New Mexico.	Cannon, Shacklette, and Bastron (1968).	Ash, 30.7 percent.
Equisetum arvense	.1	Ely, Orange County, Vt.	do	Ash, 33.7 percent. Plant on tailings from ore.
Do	.2	do	do	Ash, 29 percent. Plant near shaft on undisturbed ground.
Do	.1	Warren, Grafton County, N.H.	do	Ash, 35.9 percent. Plant on tailings.
Do	<.1	do	do	Ash, 33.2 percent. Plant on outcrop of schist.
Do	.1	Franklin, Sussex County, N.J.	do	Ash, 18.6 percent. Plant on limestone mine dump.
Do	.1	Vaucluse, Orange County, Va.	do	Ash, 21 percent.
Do	.1	Blanding, Grafton County, N.H.	do	Ash, 22.6 percent. Collected over schists.
Do	.1	Climax, Lake County, Colo.	do	Ash, 18.9 percent. Plant below upper tailings pond.
Do	.2	Black Hawk, Gilpin County, Colo.	do	Ash, 28.4 percent. Plant on alluvium below Black Cat mine.
Do	.2	do	do	Ash, 29.2 percent. Plant growing above quartz veins.
Do	.4	McGrath, Alaska	do	Ash, 14.8 percent. Plant from muskeg.
Do	.1	Red Devil, Alaska	do	Ash, 24.6 percent. Plant in ravine by mercury smelter.
Do	16	Gross Schüttinsel, Czechoslovakia.	Babička (1943)	(0.2).
Do	63	Oslany, Czechoslovakia	do	50.22 percent of the ash was silica.
Equisetum hyemale var. *robustum*	.4	Utley, Henderson County, Ky.	Cannon, Shacklette, and Bastron (1968).	Ash, 16.5 percent.
Equisetum limosum	.4	McGrath, Alaska	do	Ash, 15.1 percent. Plant from muskeg.
Do	.5	Red Devil, Alaska	do	Ash, 14.1 percent. Plant from lake fed by drain from abandoned mercury mine.
Equisetum littorale	.1	Nederland, Boulder County, Colorado.	do	Ash, 33.3 percent. Plant on mill tailings.
Equisetum palustre L	610	Oslany, Czechoslovakia	Babička (1943)	Ash is 61.20 percent silica. See *Mentha arvensis*. (0.2).
Do	Trace-.7	Yakut, U.S.S.R	Razin and Rozhkov (1966).	2 samples of entire plant. Ash, 5.5 and 2.2 percent, respectively. (1.7).
Equisetum pratense Ehrh	0-.2	do	do	4 samples of entire plant. Only 1 sample with detectable Au. Ash, in percent, 2.41-9.53, average 7.5. (2.4).
Do	.1	Slick Rock, San Miguel County, Colo.	Cannon, Shacklette, and Bastron (1968).	Ash, 24 percent. Plant on river alluvium below mill.
Do	.1	Gothenberg, Dawson County, Neb.	do	Ash, 38.2 percent.
Equisetum sylvaticum	.2	McGrath, Alaska	do	Ash, 13.2 percent. Plant from muskeg.
Do	.4	Red Devil, Alaska	do	Ash, 14.5 percent. Plant from loess near mercury mine.
Equisetum variegatum	.2	Black Canyon Spring, Jerome, Yavapai County, Ariz.	do	Ash, 27.1 percent.
Erigeron flaccidus Botsch	0	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Ash, 3.52 percent. (Trace [1].)
Iris setosa Pall. (Arctic iris)	0	do	do	Stems and leaves. Ash, 2.18 percent. (0.2).
Leucojum aestivum Zwiebel (summer snowflake).	15	Gross Schüttinsel, Czechoslovakia.	Babička (1943)	(0.6).
Linnaea borealis L. (twinflower)	0-3.0	Yakut, U.S.S.R	Razin and Rozhkov (1966).	4 samples. Entire plant. Ash, in percent: 9.81-11.0, average, 10.3 (4.5).
Lycopodium anceps Wallr. (clubmoss).	.1-.3	do	do	2 samples. Ash, in percent, 4.22 and 5.00, respectively. (0.3).
Lycopodium annotinum	.5	do	do	Ash, 4.00 percent for entire plant. (1.9).
Lycopodium clavatum L	.5	do	do	Ash, 28.02 percent (probably in error) for entire plant. (4.0).
Maianthemum bifolium (L.) Fr. Schmidt (twoleaf beadruby).	1.5	do	do	Leaves. Ash, 7.03 percent. (0.3).
Mentha arvensis (corn mint)	300	Oslany, Czechoslovakia	Babička (1943)	Sampled from the same place as an *Equisetum palustre* which contained 610 ppm Au in the ash. (0.2).
Nardosmia frigida (L.) Hook	0	Yakut, U.S.S.R	Razin and Rozhkov (1966).	Entire plant. Ash, 6.13 percent. (Trace [1].)
Paris quadrifolia var. *obovata* Ldg	0	do	do	Stems and leaves. Ash, not determined.
Pedicularis labradorica Wirsing	.6	do	do	Entire plant. Ash, 10.17 percent (Trace. [1])
Pyrola incarnata Fisch	.03	do	do	Entire plant. Ash, 0.47 percent. (0.5).
Polemonium liniflorum V. Vassil	2.5	do	do	Entire plant. Ash, 2.56 percent. (0.3).
Salsola arbusculiformis	2.5	Kyzyl-Kum, U.S.S.R	Khotamov, Lobanov, and Kist (1966).	From a fresh plant with an ash content of 9.5 percent. For air-dried weight the Au content, in ppm, is: leaves, 0.05; terminal stems, 0.15; and main stems, 0.1. Analyses by neutron activation. (0.2 ppm or less).
Salsola carinata (Russian thistle)	1.6	do	do	From a fresh plant with an ash content of 20 percent. For air-dried weight the Au content, in ppm, is: leaves, 0.02; terminal stems, 0.1; main stems, 0.2; and roots, 0.05. Analyses by neutron activation. (0.2 ppm or less).

Organism	Content in ash (ppm)	Sampling locality	Reference	Remarks
		VASCULAR PLANTS—Continued		
		Herbs—Forbs—Continued		
Salsola rigida (Russian thistle)	1.4	Kyzyl-Kum, U.S.S.R.	Khotamov, Lobanov, and Kist (1966).	From a nearly dry plant with an ash content of 18.0 percent. For air-dried weight the Au content, in ppm, is: leaves, 2.4; terminal stems, 0.05; main stems, 0.02; and roots, 0.02. Analyses by neutron activation. (0.2 ppm or less).
Sanguisorba officinalis L.	1.5	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	Entire plant. Ash, 2.4 percent. (0.2).
Tanacetum vulgare L. (common tansy).	0-1.96	do	do	5 samples. Entire plant has 0 and 0.4 ppm Au and an ash content of 4.0 and 7.8, respectively; except roots but including flowers, the Au, content is 1.96 ppm, and the ash content, 1.2 percent. The Au content of flowers is 0.5 ppm, and the ash content, 6.71 percent. Stems and leaves contain no detectable Au and had an ash content of 2.84 percent. (8.0).
Trifolium pratense L. (red clover)	1.2	do	do	Entire plant. Ash, 6.67 percent. (Trace.)[1]
Urtica sp. (nettle)	16.8	Gross Schüttinsel, Czechoslovakia.	Babička (1943)	(0.85).
Veratrum oxysepalum Turcz. (false hellebore).	1.7	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	Leaves and roots.
		Shrubs		
Alnus fruticosa Rupr. (Manchu alder).	0-.9	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	28 analyses, ash, 0.3-3.76 percent. 19 analyses of branches with leaves; Au, 0-0.03 ppm, ash 0.7-3.76 percent. (1.9). 7 analyses of branches only; Au, 0-0.005 ppm, ash, 0.3-1.5 percent. (3.4). 1 analysis of a seed capsule; Au, 0.9 ppm and ash, 0.91 percent. (4.5). 1 analysis of young shoots with leaves and seed capsules; Au, 0.4 ppm and Ash, 0.35 percent. (3.2).
Clematis vitalba (virgin's bower)	600	Oslany, Czechoslovakia	Babička (1943)	Seeds.
Do	50	Eule (Jilove) near Prague, Czechoslovakia.	do	Wood.
Do	7	do	do	Fruit.
Do	110	Oslany, Czechoslovakia	do	Wood.
Do	60	do	do	Fruit.
Corylus avellana (hazel nut, filbert).	Trace	do	do	Wood.
Do	6-9	Eule (Jilove) near Prague, Czechoslovakia.	do	
Do	20	do	do	Sampled from an old gold mine dump(?).
Cousinia hamadae	1.0	Kyzyl-Kum, U.S.S.R.	Khotamov, Lobanov, and Kist (1966).	From a dry plant with an ash content of 13.0 percent. For air-dried weight the Au content in ppm is: leaves, 0.05; upper twigs, 0.05; stems, 0.05; and roots, 0.05. Analysis by neutron activation. (0.2 ppm or less).
Dasiphora fruticosa (bush cinquefoil).	1.2	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	Entire plant except roots. Known also as *Potentilla fruticosa* L. (0.5).
Empetrum nigrum (crowberry)	0-2.5	do	do	5 samples of entire plant. Ash, 0.4-2.88 percent. (4.0).
Girgensohnia oppositiflora	2.1	Kyzyl-Kum, U.S.S.R.	Khotamov, Lobanov, and Kist (1966).	From a dry plant with an ash content of 20.0 percent. For air-dried weight, the Au content, in ppm, is: leaves, 0.26; terminal stems, 0.05; and main stems, 0.05. Analyses by neutron activation. (0.2 ppm or less).
Haplophyllum robustum (goldenweed).	11.4	do	do	From a fresh plant with an ash content of 7.0 percent. For air-dried weight the Au content, in ppm, is: leaves, 0.6; terminal stems, 0.05; main stems, 0.05; and roots, 0.02. Analyses by neutron activation. (0.2 ppm or less).
Juniperus communis (common juniper).	<0.03	North Fork of Watson Bar Creek, British Columbia, Canada.	Warren and Delavault (1950).	4 composite samples. Dry matter is 4.10 percent ash.
Do	Nil	do	do	3 composite samples. Dry matter is 4.68 percent ash.
Do	.61	do	do	From an auriferous area with an overburden of 4-8 ft. Ash, 3.25 percent (Trace).
Lagochilius intermedius	36	Kyzyl-Kum, U.S.S.R.	Khotamov, Lobanov, and Kist (1966).	From a fresh plant with an ash content of 15.0 percent. For air-dried weight the Au content, in ppm, is: seeds, 0.025; seed pods, 0.5; leaves, 3.0; terminal stems, 0.5; main stems, 0.2; and roots, 1.0. Analyses by neutron activation. (0.2 ppm or less).
Ledum palustre L. (crystal tea)	0-5.0	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	39 samples. Ash, 0.34-2.53 percent. 29 samples of entire plant; ash, 0.42-2.53 percent, Au, 0-1.5 ppm in ash. (2.0). Stems, 6 samples; ash, 0.34-1.51 percent, Au, 0-4.2 ppm in ash. (4.1). Stems with leaves; ash, 0.34 and 1.0 percent, Au, 0.3 and 1.0 ppm in ash, respectively. (2.5). Young shoots with leaves and seeds; ash, 1.5 percent, Au, 3.6 ppm in ash. (4.7). Roots; ash, 1.52 percent, Au, 5.0 ppm in ash. (4.1).
Lonicera altaica Pall. (honeysuckle).	0-3.5	do	do	6 samples with ash from 1.54-7.89 percent. 5 samples of stems, branches, and leaves; ash, 1.54-7.89 percent, Au, 0-3.5 ppm is ash. (1.9). Au content in ash of berries, 0.7 ppm.

TABLE 2.—*Gold content of plants*—Continued

Organism	Content in ash (ppm)	Sampling locality	Reference	Remarks
		VASCULAR PLANTS—Continued		
		Shrubs—Continued		
Nanophyton erinaceum	0.3	Kyzyl-Kum, U.S.S.R.	Khotamov, Lobanov, and Kist (1966).	From a dry plant with an ash content of 16.0 percent. For air-dried weight the Au content, in ppm, is: leaves, 0.05; terminal stems, 0.05; main stems, 0.05; and roots, 0.05. Analyses by neutron activation. (0.2 ppm or less).
Ribes procumbens Pall. (gooseberry).	Trace [1]	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	Branches. Ash, 1.09 percent. (0.5).
Rosa acicularis Lindl. (prickly rose).	0-2.2	do.	do.	16 samples with an ash content of 0.6-3.89 percent. 10 samples of the entire plant; ash, 1.0-3.89 percent, Au, 0-2.2 ppm in ash. (1.2). 3 samples of entire plant without berries; ash, 0.8-2.25 percent, Au, 0.04-0.2 ppm in ash. (1.9). Berries, ash, 2.64 percent, Au, 0 ppm. (4.5). Plant at surface(?) of ground; ash, 0.6 and 0.69 percent, Au, 15.0 and 0.7 ppm in ash, respectively. (8.0).
Rosa canina (dog rose)	Trace	Gross Schüttinsel, Czechoslovakia.	Babička (1943)	Hips and wood.
Rubus arcticus L. (Arctic bramble)	0-10.0	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	3 analyses. Entire plant, ash, 0.73-4.4 percent. (4.5).
Rubus sachalinensis Levl.	0-2.8	do.	do.	6 analyses. Entire plant, ash, 1.1-7.03 percent. (6.0).
Rubus saxatilis L. (stone berry)	.15	do.	do.	Entire plant. Ash, 7.5 percent. (1.9).
Salix sp. (willow)	1.02	North Fork, Watson Bar Creek, British Columbia, Canada.	Warren and Delavault (1950).	Ash, 2.20 percent. From an auriferous area with an overburden of 4-8 ft.
Do.	Nil	do.	do.	2 samples. Ash, 6.36 percent. From a nonauriferous area.
Salix caprea L.	0, .03	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	2 samples of branches with leaves. Ash, 2.25 percent. (4.5).
Salix floderusii Nakai.	0-.005	do.	do.	2 samples of branches with leaves. Ash, 0.8 and 1.83 percent. (0.2).
Salix kolymensis O. V. Seem.	0	do.	do.	Branch with leaves. Ash, 1.86 percent. (0.2).
Salix pentandra L.	0-.02	do.	do.	12 samples. Ash, 0.82-4.72 percent. 9 samples of branches with leaves; ash 1.41-4.72 percent, Au, 0-trace in ash. (0.5). 3 samples of branches without leaves; ash, 0.82-1.92 percent, Au, 0-0.06 ppm in ash. (0.5).
Salix viminalis L.	0	do.	do.	Branches with leaves; ash, 5.6 percent. (0.2).
Salix xerophila Floder.	0	do.	do.	Branches with leaves; ash, 1.93 percent (0.6).
Sorbus sibirica Hedl.	.4, .6	do.	do.	Berries; ash, 5.62 percent, Au, 0.4 ppm in ash. (1.9). Branches and leaves; Au, 0.6 ppm in ash. (1.9).
Spiraea media (Fr.) Schmidt (oriental spirea).	0	do.	do.	Entire plant. Ash, 1.9 percent. (0.2).
Vaccinium myrtillus L. (bilberry, blueberry).	0, 0.2	do.	do.	Ash, 4.19 and 10.5 percent, respectively. Entire plant. (1.9).
Vaccinium uliginosum L. (bog bilberry).	0-4.6	do.	do.	18 samples. Ash, 0.6-3.0 percent. 14 samples of the entire plant; ash, 0.6-3.0 percent, Au, 0-0.2 ppm in ash. (4.5). Stems and branches; ash, 0.65 and 0.82 percent, Au, 0 and 0.004 ppm in ash, respectively. (Trace [1]). Stems and roots; ash, 1.0 percent, Au, 0.3 ppm in ash. (1.9). Stems, branches, and leaves; ash, 0.7 percent, Au, 4.6 ppm in ash. (3.2).
Vaccinium vitis-idaea L. (cowberry).	0-.8	do.	do.	17 samples of entire plant; ash, 0.7-4.59 percent, Au, 0-0.8 ppm in ash. (2.5). Berries, Au, 0.7 ppm in ash. (0.5).
		Trees		
Betula sp. (birch)	.6	Kuznetsk Ala-Tau, U.S.S.R.	Zvyagintzev (1941)	Trunk and branches 1 m apart.
Betula fruticosa Pall. (Altai birch)	0	Yakut, U.S.S.R.	Razin and Rozhkov (1966).	2 samples. Ash, in branches, 0.73 percent, in branches and leaves, 1.82 percent. (0.5)s
Betula hybrida Schneid.	0-1.7	do.	do.	17 samples. Ash, 0.5-2.33 percent. 8 samples of branches with leaves; ash, 0.5-2.2 percent, Au 0-1.7 ppm in ash. (3.2). 7 samples of branches; ash, 0.5-2.33 percent, Au 0-0.005 ppm in ash. (3.4). 2 samples of leaves; ash, 2.2 and 2.33 percent, Au 0.1 and 0 ppm in ash, respectively. (2.4).
Betula middendorffii Trautv. et Mey. (Middendorff birch).	0-2.5	do.	do.	17 samples. Ash, 0.5-3.95 percent. 11 samples of branches and leaves; ash, 0.9-3.95 percent, Au 0-2.5 ppm in ash. (4.0). Branches, 6 samples; ash, 0.5-0.91 percent, Au 0-0.005 ppm in ash. (2.5).
Betula platyphylla Sukatch. (Asian white birch).	0-1.3	do.	do.	7 samples. 6 samples of branches with leaves; ash, 0.96-3.24 percent, Au 0-1.3 ppm in ash. (4.5). Ash in leaves, 1.86 percent, Au in ash, 0.1 ppm. (Trace [1]).
Diptychocarpus strictus (Gurjunoil tree).	.05-.26	Kyzyl-Kum, U.S.S.R.	Khotamov, Lobanov, and Kist (1966).	From a dry plant with an ash content of 20.0 percent. For air-dried weight, the Au content, in ppm, is: leaves, 0.26; terminal stems, 0.05; and main stems, 0.05. (0.2 ppm or less).

Organism	Content in ash (ppm)	Sampling locality	Reference	Remarks
VASCULAR PLANTS—Continued				
Trees—Continued				
[Iron wood]	0.15	Omai Valley, British Guiana.	Lungwitz (1899)	Pieces of trunk near the roots. In subsurface, a gold-bearing aplite.
Larix dahurica Turcz. (larch)	0-2.6	Yakut, U.S.S.R	Razin and Rozhkov (1966).	8 samples. Ash, 0.2-1.3 percent. 4 samples of entire plant; ash, 0.4-1.3 percent, Au, 0-1.4 ppm in ash. (1.7). 2 samples of young shoots with needles and cones; ash, 0.2 and 0.65 percent, Au, 0.2 and 0.4 ppm in ash, respectively. (8.0). Wood and bark; ash, 0.96 percent, Au, 2.6 ppm in ash. (0.2). Plant without roots; ash, 1.06 percent, Au, 0 ppm in ash. (0.2).
Picea sp	1.27	Kuznetsk Ala-Tau, U.S.S.R.	Zvyagintzev (1941)	From the trunk of an 18- to 20-year-old sapling.
Do	6	do	do	Wood and branches from the aforementioned tree.
Picea obovata Lab. (Siberian spruce)	0-.8	Yakut, U.S.S.R	Razin and Rozhkov (1966).	4 samples. Ash, 0.3-2.2 percent. 2 samples of needles and twigs; ash, 1.5 and 2.2 percent, Au, 0.7 and 0 ppm in ash, respectively. (0.5). Cones; ash, 0.8 percent, Au, 0.8 ppm in ash. (0.5). Trunk, branches, and needles; ash, 0.3 percent, Au, 0 ppm in ash. (Trace [1]).
Pinus contorta (lodgepole pine)	Nil	North Fork, Watson Bar Creek, British Columbia, Canada.	Warren and Delavault (1950).	3-sample composite. Ash, 2.12 percent.
Do	<.03	do	do	2-sample composite. Ash, 2.42 percent.
Do	Nil	do	do	Ash, 1.90 percent.
Pinus ponderosa (western yellow pine).	Nil	do	do	5-sample composite. Ash in dry matter, 4.68 percent.
Do	Nil	do	do	5-sample composite. Ash in dry matter, 5.37 percent.
Do	Nil	do	do	10-sample composite. Ash in dry matter, 2.66 percent.
Pinus pumila Regel. (Japanese stone pine).	0-2.1	Yakut, U.S.S.R	Razin and Rozhkov (1966).	3 samples of twigs and needles; ash, 0.47-2.00 percent. (1.9).
Pinus sibirica (Rupr.) Mayr. (Siberian pine).	0-1.2	do	do	6 samples; ash, 0.35-1.31 percent. 3 samples of entire plant without roots; ash, 0.57-1.31 percent, Au, 0-0.4 ppm in ash. (0.2). 2 samples of twigs and needles; ash, 0.35, Au, trace [1]-0.4 ppm in ash. (3.2). Trunk; ash, 0.42 percent, Au, 1.2 ppm in ash. (3.2).
Pinus sylvestris L. (Scotch pine)	0-.9	do	do	46 samples; ash, 0.13-5.74 percent. 28 samples of entire plant, except roots; ash, 0.25-1.06 percent, Au, 0-0.3 ppm in ash. (3.0). 5 samples of entire plant; ash, 0.21-1.20 percent, Au, 0-0.2 ppm in ash. (1.4). Roots, 3 samples; ash, 0.51-5.74 percent, Au, 0.1-0.9 ppm in ash. (3.0). 4 samples of needles and twigs; ash, 0.25-0.96 percent, Au, 0-0.5 ppm in ash. (1.9). 2 samples of needles; ash, 0.18 and 3.50 percent, Au, 0.4 and 0.2 ppm in ash, respectively. (0.8). Branches; ash, 1.17 percent, Au, trace [1] in ash. (0.). Bark; ash, 0.56 percent, Au, 0 ppm in ash. Wood; ash, 0.13 percent, Au, 0 ppm in ash. (3.0). Bark and wood; ash, 0.52 percent, Au, 0.5 ppm in ash. (3.0).
Populus sp	2.0	Kuznetsk Ala-tau, U.S.S.R.	Zvyagintzev (1941)	Trunk and branches 1 m apart.
Populus tremula L. (European aspen).	0-2.1	Yakut, U.S.S.R	Razin and Rozhkov (1966).	22 samples. Ash, 0.53-4.34 percent. 16 samples, branches, and leaves; ash, 0.56-4.34 percent, Au, 0-0.5 ppm in ash, (0.6). 4 samples of branches without leaves; ash, 0.99-2.9 percent, Au, 0-0.2 ppm in ash, (0.5). 2 samples of leaves; ash, 0.53 and 2.52 percent, Au, 0 and 2.1 ppm in ash, respectively. (8.8).
Populus tremuloides (quaking aspen)	.89	North Fork, Watson Bar Creek, British Columbia, Canada.	Warren and Delavault (1950).	Ash, 2.40 percent. In an area of known mineralization with an overburden of 4-8 ft.
Do	.33	do	do	2-sample composite. Ash, 7.14 percent in dry material.
Do	Nil	do	do	2-sample composite. Ash, 6.90 percent in dry material.
Pseudotsuga taxifolia (Douglas-fir)	.65	do	do	More recently considered *Pseudotsuga menziesii* (Wirt.) Franco. Ash, 2.30 percent. In an area of known mineralization with an overburden of 4-8 ft.
Do	Nil	do	do	12-sample composite. Ash, 3.65 percent.
Do	Nil	do	do	5-sample composite. Ash, 4.75 percent.
Do	Nil	do	do	5-sample composite. Ash, 3.00 percent.
Tilia parvifolia (linden, basswood)	10	Oslany, Czechoslovakia	Babička (1943)	Blossoms.

[1] A trace seems to be between 0.1 to 0.001 ppm as cited by Razin and Rozhkov (1966).

in soil on which the mosses grew (given in parenthesis) was generally less than the amount of gold found in the ashes of the plants.

HERBS

The herbs include the largest variety of plants sampled for gold. Many replicate analyses have been made for some species. The herbaceous plants are shown to contain gold which ranges, in their ash, from 0 to 610 ppm. The extremely high value—the highest value known to be reported for a plant—was given by Babička (1943) for the marsh horsetail, *Equisetum palustre* which grew in the gold-mining region of Oslany, Czechoslovakia, where the gold content of the soil was reported to be only 0.2 ppm. In the ash from two other specimens of *Equisetum arvense*, Babička detected 16 and 63 ppm gold. Because of the possibility that species of *Equisetum* may be accumulators of gold, Cannon, Shacklette, and Bastron (1968) examined 22 collections of these plants that were gathered throughout the United States. From their analyses of these plants, they concluded that the average amount of gold to be expected in this vegetation is less than 0.2 ppm and consequently *Equisetum* would not be useful in prospecting for gold. In addition they noted that the high values of 610 ppm gold in the ash of *E. palustre* and 63 ppm gold in the ash of *E. arvense* may be erroneous due to the probability, in the original analyses, that the sulfides of copper and several other metals were reported as gold. Other workers have reported about the same amounts of gold in the ash of *Equisetum* as found by Cannon, Shacklette, and Bastron. For instance, Warren and Delavault (1950) reported from 0.17 to 0.34 ppm (average 0.3 ppm) gold in the ashes of four plants, and Razin and Rozhkov (1966) reported from 0 to 0.7 ppm gold in the ashes of six plants.

In the ashes of the forbs, Babička reported gold contents of 4.36 ppm and more. By comparison, the average amount of gold in the ashes of forbs as reported by other workers who succeeded Babička rarely exceeded the minimum amount reported by him.

Although differences in the gold content of various parts of plants were observed, no plant part appeared to be superior to any other part in its amount of gold. The parts compared were roots, main and terminal stems, leaves, flowers, seeds, and seed pods.

The amount of gold in the plant ash reported by Babička greatly exceeded the gold content of the soil. However, other workers (Khotamov, Lobanov, and Kist, 1966, and Razin and Rozhkov, 1966) show much smaller differences. Many plant ashes contained less gold than the soil in which they grew (table 2).

There appears to be no significant differences in the gold content of forbs and of grasses and sedges. The gold content in the ashes of grasses and sedges ranged from 0 to 8.6 ppm. The maximum gold content of the soil was 8 ppm.

As a gold-sampling device of the flowering plants in a neighbourhood, honey has been analyzed for gold by Berg (1928) but without success.

SHRUBS

The amount of gold in the ashes of shrubs varied from 0 to 600 ppm. Excluding the amounts reported by Babička, the maximum amount was 36 ppm given by Khotamov, Lobanov, and Kist (1966) who used neutron-activation methods of analyses for plants.

Khotamov, Lobanov, and Kist (1966) analyzed the separate parts of a few shrubs (table 2). More gold was detected in the leaves of *Girgensohnia oppositiflora, Haplophyllum robustum*, and *Lagochilius intermedius* than in their roots, terminal stems, or main stems, but in *Nanophyton erinaceum* the same amount of gold was reported for these various parts.

Razin and Rozhkov (1966) reported a maximum gold content for the ash of shrubs as 10 ppm (*Rubus arcticus*) and the maximum gold content of the soil, 4.5 ppm. Near some other shrubs the maximum gold content of the soil was 8 ppm. They found in about two-thirds of the soil and plant samples analyzed that the maximum amount of gold in the soil exceeded that in the ashes of shrubs.

TREES

The gold content of trees is similar to that of other vegetation. The amount of gold reported in tree ashes varies from 0 to 10 ppm, the high amount being reported by Babička (1943) for the ash from the blossoms of *Tilia parvifolia*. Gold was not detected in the ashes of a variety of trees. No tree part was shown to be consistently higher in gold content than any other part. According to the analyses of Razin and Rozhkov (1966), the maximum amount of gold found in the soil near the analyzed trees was usually greater than the gold in the ashes of the adjacent plants.

SUMMARY

The maximum amount of gold that has been reported in the ash of plants is 610 ppm (Babička, 1943). However there is serious doubt regarding the reliability of some of the values reported by Babička; probably the reported maximum amount of gold in plant ash is much less. The maximum values given in table 2 by other investigators for gold in the ash of some terrestrial vegetation is: Cannon, Shacklette, and Bastron (1968), 0.5 ppm; Warren and Delavault (1950), 1.02 ppm; Razin and Rozhkov (1966), 19.2 ppm; Khotamov, Lobanov, and Kist (1966), 36 ppm; Zvyagintzev (1941), 6 ppm; Lungwitz (1899), 0.15 ppm; and Stark (1943), 1.7 ppm. At present the amount of data is insufficient to show that one part of a plant contains more gold than any other part, although a few analyses by Khotamov, Lobanov, and Kist (1966) suggest the possibility that leaves may contain more gold than other plant organs. In addition no group of plants seems to contain consistently more gold than any other group.

Razin and Rozhkov (1966) found that the maximum amount of gold in the soil (usually the C horizon) exceeded that shown for the ash of most of the plants which they analyzed. However Khotamov, Lobanov, and Kist (1966) believe that "the concentrations of gold in plants exceeds considerably the gold content in the soil." Analyses of the gold content of mull (humus-rich forest soil) ash that was derived chiefly from lodgepole pine (*Pinus contorta*), limber pine (*Pinus flexilis*), and aspen (*Populus tremuloides*) in the Empire mining district of Colorado was, with few exceptions, higher than that in the underlying soil (Curtin and others, 1968). Although the concentrations of gold in the ash of plants generally appear to exceed the gold content of the soil, the differences between the gold content of the ash of plants to that of the earth's crust and various rock types appears to be much greater. Based on neutron-activation analyses, the gold content of igneous rocks is given as 3.6 ppb, for sedimentary rocks, 5.4 ppb, and for metamorphic rocks, 4.6 ppb (Jones, 1969), and for the earth's crust, 1 to 6 ppb (Jones, 1968). Probably, then, the amount of gold in plant ash may be one or more magnitudes higher than the amount found in the rocks in the earth's crust.

GOLD CONTENT OF ANIMALS

Gold has been looked for in only a few animals. Known analyses have been made on four different types of insects, seven different types of marine organisms, and seven types of warm-blooded animals.

Cockchafers (scarabaeid beetles) have been found to be auriferous when indigenous to Oslany, a gold-mining region in Czechoslovakia, but not when from the region of Propast near Stribrna Skalica (Bohemia). The gold content of cockchafers can be reduced by feeding them nonauriferous plants (Babička, Komárek, and Némec, 1945). Razin and Roshkov (1966) looked for but did not detect gold in the water beetle (*Dytiscus* sp.) or in the carpenter ant (*Camponotus vagus*), although 0.4 ppm gold was obtained from the ash of a bee (*Vispidae* sp.).

The amount of gold found in some marine animals is shown in table 3. Analyses made by neutron activation are much lower than those made by older methods. For instance, Noddack and Noddack (1939) reported from 7 to 30 ppb gold in the dry matter of several marine animals. By contrast values obtained by neutron-activation methods vary from 0.0012 to 0.126 ppb gold in the dry material (Fukai and Meinke, 1962; Bowen, 1968; Oka, Kato, and Sasaki 1964). The least amount of gold was found in the dry matter of the muscle of the mackerel, *Pneumatophorus japonicus*. Bowen (1968) reported 0.126 ppb gold in the dry matter of a sponge from Plymouth, England (table 3). He thought that this value was due to the relatively high initial gold content of sea water in the area where the sponge grew and to the scleroprotein structure of the sponge which resembles some artificial polymers. According to Bowen, gold can be concentrated by absorption or adsorption on certain artificial polymers. In the dried matter of fishes, Fukai and Meinke (1962) found 0.1 ppb gold in the soft parts. This was considerably more gold than was found in the soft parts of the mackerel *Pneumatophorus japonicus* by Oka, Kato, and Sasaki (1964). The average amount of gold in the dry matter of marine organisms seems to be about the same as that which occurs in sea water. This conclusion is based on neutron-activation methods of analysis for both. The figures used in computing the average gold content of marine animals are taken from table 3, and, in addition, include the 0.1 ppb gold reported by Fukai and Meinke (1962). This average is 0.04 ppb and is close to that of 0.05 ppb for sea water. The values given for comparison are obviously based not only on too few analyses but are also probably not representative of their kind.

Gold has been detected in birds, cows, deer, and man and has been administered to laboratory animals such as rats and mice. Gold was looked for

TABLE 3.—*Gold content of marine animals*

[See table 2 for comparison with the marine plant, *Ulva* sp.]

Organism	Content in dry matter (ppb)	Reference	Remarks
Halichondria panicea (sponge).	0.126	Bowen (1968) .	From Plymouth, England. Mean of 2 replicates.
Halichondria magnicanulosa (sponge).	.023	.....do.........	From Hawaii. Mean of 2 replicates.
Mycale cecilia (sponge)....	.029	.....do.........	Do.
Taxadocia violacea (sponge).	.029	.....do.........	Do.
Tedania sp. (sponge)......	.055	.....do.........	Do.
Zygomycale parishii (sponge).	.018	.....do.........	Do.
Halichondria sp. (sponge).	10	Noddack and Noddack (1939).	
Asterias rubens (starfish)..	30	.....do.........	
Brissopsis lyrifera (sea urchin).	7	.....do.........	Shell.
Strichopus tremulus (sea cucumber).	24	.....do.........	
Tapes japonica (clam)....	.057	Oka, Kato, and Sasaki (1964).	Content of soft parts. Au in ash, 0.79 ppb.
Pandalus sp. (shrimp)....	.0028	.....do.........	Content of soft parts. Au in ash, 0.046 ppb.
Pneumatophorus japonicus (mackerel).	.0012	.....do.........	Content of muscle. Au in ash, 0.026 ppb.

but not detected in the bones and teeth of a wild pig shot in the gold-mining region of Oslany, Czechoslovakia (Babička, 1943).

A number of birds were examined for gold by Razin and Rozhkov (1966). These consisted of three northern spruce crossbills, *Loxia curvirostra curvirostra* L., which contained from no detectable gold to 1.1 ppm in their ash (2.43 to 2.80 percent), four Siberian white crossbills, *Loxia leucoptera bifasciata* Brehm., which contained from no detectable gold to as much as 1.5 ppm in their ash (2.36 to 2.75 percent), one common bunting, *Emberiza leucocephalos* Gm., which contained 1.2 ppm in its ash (4.13 percent), two unidentified buntings, *Emberiza*, which contained no detectable gold in one (3.67 percent ash) and 0.3 ppm gold in the other (3.61 percent ash), three Siberian spotted pipits, *Anthus hodgsoni inopinatus* Hart. et Steinb., which contained from 0.1 to 0.9 ppm gold in their ash (4.83 to 6.15 percent), and one redwing thrush, *Turdus naumanni naumanni* Temm., which contained 0.1 ppm gold in its ash (1.64 percent).

Antlers from deer harvested in Czechoslovakia and in the United States have been analyzed for gold. Babička, Komárek, and Némec (1945) analyzed different parts of the roebuck from Oslany, Czechoslovakia, a gold-bearing region. They found gold in the ashes of the hair of the roebuck, from 3 to 8.5 ppm and an inconsiderable amount in the hooves, but most in the ash of the antlers, 60 ppm in one animal and 68 ppm in another animal. The points of the antlers contained the most gold. No gold was found in the antlers of deer shot in the eastern Carpathian Mountains or near Karlstein. By contrast, the antlers of 15 mule deer (*Odocoileus hemionus*), harvested from four gold-mining regions in the United States (in the mother lode country, California, near Ouray, Colo., Lead, S. Dak., and Eureka, Utah), contained about the same amount of gold in their ashes as occurs in relatively nonauriferous rocks (Jones, 1969). Neutron-activation analyses were made by members of the U.S. Geological Survey on the 1- and ¼-inch-long tips of the antlers of these deer. The amount of gold found in the ashes of the 1-inch-long tips ranged from 0.5 to 6.4 ppb and averaged 2.3 ppb. In the ashes of the ¼-inch-long tips from five of these deer, the amount of gold detected ranged from 0.3 to 28.3 ppb and averaged 7.0 ppb. Thus it seems that more gold, per unit volume, occurs at the very tips of the antlers.

Gold has been found in cow liver and brains, and in human blood, feces, and urine (Bertrand, 1932). Bertrand detected 0.3 ppm gold in human blood, 0.2 ppm in cow liver, but most of all, the brain of an ox yielded 14 ppm which indicates a high value for brains. The amount of gold in 32 samples of wet human liver tissue ranged from 0.03 to 0.79 ppb and averaged 0.057 ppb (Parr and Taylor, 1963). In human blood the mean gold content is about 0.004 ppb, in erythrocytes about 0.008 ppb, and in plasma, about 0.006 ppb (Bagdavadze and others, 1965). The amount of gold in whole normal and uremic human bloods was found to be the same (Aripova and Prikhid'ko, 1965). The amount of gold detected in human hair varied from 0.8 to 430 ppb (Bate and Dyer, 1965), the amount of gold in the hair of a man from Napier, New Zealand, averaged 270 ppb and from Hastings, New Zealand, 290 ppb. The average amount of gold in the hair of a man from Tennessee was 430 ppb. The amount of gold found in human teeth ranges from 10 to 30 ppb dry weight (Soeremark and Samsahl, 1962; Lundberg and others, 1965). Although no significant differences could be noted in the gold content of teeth on the basis of sex or between the upper or lower jaws, unerupted (impacted) bicuspids contained no detectable gold.

Gold has been administered to rats and mice and the effects noted. The administration of gold thioglucose to mice results in a focal accumulation of gold in the hypothalamus (Debons and others, 1962). Gold given to white rats by Kalistratova, Moskalev, and Serebryakov (1966) resulted in an accumulation of some of the gold mainly in the liver, spleen, and lymphatics. Katakura (1965) noted that gold administered intravenously in colloidal form in rats concentrated chiefly in the liver and spleen and less was retained in the lungs, kidneys, and femoral bones.

SUMMARY

The amount of gold occurring in animals varies greatly. Values obtained by neutron activation show as little as 0.0012 ppb gold has been found in the dry matter of fish muscle and as much as 430 ppb gold in human hair. Excluding the earlier work of Noddack and Noddack (1939), marine animals contain, by far, the least amount of gold and terrestrial animals contain the most gold. Bones, teeth, and phosphorite are calcium phosphates with comparable gold contents. Neutron-activation analyses of composite samples of rock phosphorites from Morocco and the United States contained from 0.5 to 3.1 ppb gold (Z. S. Altschuler, oral commun., 1969), human teeth show 10 to 30 ppb gold, and the ash of deer antlers from 0.5 to 28.3 ppb gold. These naturally occurring calcium phosphate compounds appear to be similar in their gold content, irrespective of their origin, and probably reflect the gold level of their environment.

The known content of gold in animals apparently supports Vinogradov's (1953) observation that the amount of gold found in animal organs is entirely casual and that there are no auriferous animals anywhere in the world.

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