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Concentration of gold in natural waters

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ABSTRACT

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The purpose of this paper is to investigate the amount of gold present in natural waters. One hundred and thirty-two natural water samples were collected from various sources and analyzed for gold by the latest techniques. Background values for gold in natural waters range from <0.001 to 0.005 ppb, and anomalous values range from 0.010 to 2.8 ppb. Waters collected from mineralized areas have a mean gold value of 0.101 ppb, whereas waters collected from unmineralized areas have a mean of 0.002 ppb. Some of the high gold values reported in the earlier literature were probably due to interferences by high salt content in the sample and/or lack of proper filter procedures.

INTRODUCTION

The concentration of gold in natural water has long been of interest to man, especially during the last hundred years. The first analyses for gold in water were made in 1872 by Sonstadt (1872). Gold concentration in sea water was reported to be in the range of 2–64 ppb (ug l^{-1}) during the latter part of the 19th century (Stark, 1943). It was thought that there was enough gold in sea water to pay for the German war debt. In 1918 Fritz Haber started analyzing water from river estuaries for gold and found that gold concentrations increased with the salt concentration of the water. He analyzed more than 4,000 water samples from the Atlantic Ocean and found an average gold concentration of 0.004 ppb (Haber, 1927). He concluded that it was not economical to extract gold from river or sea waters.

A summary report by Jones (1970) gives a range of gold concentrations in natural waters of 0.001–44 ppb for sea water, 0.003–4.7 ppb for river water, and 0.001–2.2 ppb for spring/ground water. These data were gathered from 1927 to 1969. Boyle's (1979) report shows a similar range of gold concentrations in natural waters. Table 1 summarizes gold concentrations in natural waters reported since 1969.

It seems that discrepancies about the high amount of gold concentrated in

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TABLE 1

Concentration of gold in natural water reported since 1969

Sample source	Concentration of gold (ppb)	Reference
*Springs/ground waters	0.1 -4.0	Chernyayev et al., 1969
*Springs	0.03 -1.6	Goleva et al., 1970
*Springs	0.010-0.037	Gosling et al., 1971
*Springs	<0.001-1.4	Volkov and Shakhbazova, 1975
Springs/ground waters	0.005 average	Boyle, 1979
Hot springs	0.001-2.2	Weissberg, 1969
Streams	0.001-0.057	Gosling et al., 1971
*Streams	0.09	Kaspar et al., 1972
Streams/rivers	<0.005 average	Boyle, 1979
Streams	<0.001-0.007	Brooks et al., 1981
*Streams	0.001-0.140	Turner and Ikramuddin, 1982
Streams	<0.001-0.003	Hamilton et al., 1983
*Streams	<0.001-0.130	Hamilton et al., 1983
Streams	0.050	Wilson et al., 1984
Streams	<0.001-0.003	Hall et al., 1986
Sea waters	0.006 average	Chernyayev et al., 1969
Sea waters	0.001-0.025	Wood, 1971
Sea waters	0.004	Levinson, 1974
Sea waters	0.005	Brooks et al., 1981
*Mine drainages	<0.001-0.150	Gosling et al., 1971
*Mine drainages	0.18	Kaspar et al., 1972
*Mine drainages	0.03 -10.0	Mineyev, 1976

*Samples collected from mineralized areas

natural waters exist in some of these reports. In this study, 132 water samples were collected from various sources and analyzed for gold by the latest techniques for a threefold purpose: first, to understand or eliminate some of these discrepancies; second, to build a data base for the amount of gold present in natural waters; and third, to determine if there is a difference in gold concentration between water samples from a mineralized area and those from an unmineralized area.

SAMPLING AND ANALYTICAL METHODS

Water samples were collected in one-liter polyethylene bottles. The bottles were rinsed with 0.5% (v/v) bromine-4N hydrobromic acid solution and with deionized water. The samples were shipped to the U.S. Geological Survey laboratory in Denver, Colorado, for filtering and acidification. Samples were filtered through a Millipore[1] HAWP filter (diameter, 47 mm; pore size, 0.45 μm)

[1]Use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

and acidified with 10 ml of 5% (v/v) bromine-hydrochloric acid solution. The addition of the acid-bromine solution prevents adsorption of gold on the container walls (Chao et al., 1968).

Most of the samples were analyzed by the anion-exchange graphite furnace atomic absorption spectrophotometric (GFAAS) method of McHugh (1986). A few samples were analyzed by the evaporation GFAAS method (McHugh, 1984).

RESULTS AND DISCUSSION

Table 2 shows the sample number, sample source, location, and concentration of gold in ppb. Samples were collected mostly from the western United States and Alaska but also from Pennsylvania, the Atlantic and Pacific Oceans, the South Pacific area, the Virgin Islands, New Zealand, Australia, and Chile. Figure 1 shows histograms for gold concentrations in stream and spring waters. Figure 2 shows histograms for gold concentrations in well, brine well, and hot spring waters. Figure 3 shows histograms for gold concentrations in sea waters and mine drainage waters.

The sea water samples have the lowest concentration of gold with a mean of 0.001 ppb; well water, streams, and springs have higher concentrations with means of 0.002, 0.004, and 0.003 ppb, respectively. Hot spring samples average 0.012 ppb, but the one sample from Champagne Pool, New Zealand (sample no. JM060), with a value of 0.140 ppb increases the mean for hot springs by 0.009 ppb. Brine well samples, represented by only four samples, have a mean gold value of 0.022 ppb. All the brine samples are from southern California desert areas. Many samples of brine have been found to contain high amounts of trace metals including gold. Mine drainage samples, as might be expected, have the highest mean gold value of 0.322 ppb.

Gold is found in natural waters as complex ions or as particulates of colloidal size (Lakin et al., 1974). All the samples were filtered through a 0.45-μm filter to remove debris and fine sediments that could give erroneously high soluble gold values in the analytical procedure. A 0.45-μm filter was arbitrarily set to separate "soluble" and particulate gold. An acid-bromine solution was added to make sure all gold following filtration was solubilized. This method insured that all salt and iron compounds were removed through anion exchange and/or solvent extraction. These compounds cause interferences which can also give erroneously high gold values.

When filtering a sample to prepare it for gold analyses, the filter that is used should have a minimum pore size of 0.45 μm. However, a filter with 1.2-μm pore size was used with good results by Hamilton et al. (1983).

Most of the high gold values in natural waters that were reported in earlier studies can be accounted for by two factors: (1) high salt concentrations that are found in sea water, hot springs, brines, and certain other types of water

TABLE 2

Concentration of gold from 132 water samples

Sample no.	Sample source	Location	Concentration of gold (ppb)
JM001	spring	spring, east-central Nevada	0.002
*JM002	spring	Silver Park Spring, east-central Nevada	0.005
*JM003	spring	Bradshaw Spring, east-central Nevada	0.004
*JM004	well	Bagdad well, Arizona	0.001
JM005	well	irrigation well, southern Arizona	<0.001
JM006	well	irrigation well, southern Arizona	0.008
JM007	well	irrigation well, southern Arizona	0.002
JM008	well (brine)	well, desert, southern California	0.010
*JM009	mine drainage	Keystone mine, northern California	0.001
*JM010	well (brine)	Searles Lake, desert, southern California	0.036
*JM011	well (brine)	well, desert, southern California	0.035
JM012	well (brine)	well, desert, southern California	0.007
*JM013	mine drainage	Iron Mountain mine, California	0.034
*JM014	stream	Crevice Creek, northern Alaska	0.007
*JM015	stream	Linda Creek, northern Alaska	0.005
*JM016	stream	Vermont Creek, northern Alaska	0.003
JM017	stream (glacier water)	glacier, southern Alaska	<0.001
*JM018	mine drainage	Placer mine, northern Alaska	0.023
JM019	well	domestic well, eastern Pennsylvania	0.001
JM020	well	domestic well, eastern Pennsylvania	0.002
JM021	well	domestic well, eastern Pennsylvania	<0.001
JM022	well	geothermal well, California	0.001
JM023	well	geothermal well, California	0.003
JM024	spring	spring, northern California	0.002
JM025	spring	Soda Dam Spring, New Mexico	0.002
JM026	spring	spring, northern California	0.001
JM027	spring	Ney Spring, California	0.017
JM028	spring	Pequop Spring, Nevada	0.001
JM029	spring	Curtis Spring, Nevada	0.001
JM030	spring	Barrel Spring, Nevada	0.001
JM031	spring (hot)	Golconda Spring, Nevada	0.001
JM032	spring (hot)	Leech Spring, Nevada	<0.001
JM033	spring (hot)	Seven Devils Spring, Nevada	<0.001
JM034	spring (hot)	Seven Devils Spring, Nevada	<0.001
JM035	spring	Kyle Spring, Nevada	<0.001
JM036	spring	Sand Spring, Nevada	<0.001
JM037	spring	Coso, California	<0.001
JM038	spring	Coso, California	<0.001
JM039	spring	Coso, California	<0.001
JM040	spring	Coso, California	<0.001
JM041	spring	Coso, California	0.020
JM042	stream	St. John, Virgin Islands	0.001
JM043	stream	St. John, Virgin Islands	0.001

TABLE 2 (continued)

Sample no.	Sample source	Location	Concentration of gold (ppb)
JM044	sea water	Caribbean Sea	<0.001
JM045	sea water	Caribbean Sea	<0.001
JM046	sea water	Atlantic Ocean, Massachusetts	<0.001
JM047	sea water	Atlantic Ocean, Massachusetts	<0.001
JM048	sea water	Pacific Ocean, California	0.002
JM049	sea water	Pacific Ocean, California	0.001
JM050	sea water	south Pacific Ocean, Palau	<0.001
JM051	sea water	south Pacific Ocean, Palau	<0.001
JM052	stream	Republic of Palau	<0.001
*JM053	stream	Republic of Palau	<0.001
*JM054	spring (hot)	Lihir Spring, New Guinea	<0.001
*JM055	mine drainage	Golden Horn mine area, Flat, Alaska	<0.001
JM056	stream	Slate Creek, Flat, Alaska	0.004
JM057	spring	spring, Flat, Alaska	0.002
JM058	stream	Glen Gulch, Flat, Alaska	0.006
JM059	stream	Black Creek, Flat, Alaska	<0.001
*JM060	spring (hot)	Champagne Pool, New Zealand	0.140
*JM061	spring	Ravenswood Spring, Australia	0.002
JM062	stream	Straight Creek, Henry Mountains, Utah	0.002
JM063	stream	Straight Creek, Henry Mountains, Utah	0.003
JM064	stream	Straigth Creek, Henry Mountains, Utah	0.007
JM065	stream	Straight Creek, Henry Mountains, Utah	0.003
*JM066	stream	Eagle Creek, Alaska	0.003
*JM067	stream	Ester Creek, Alaska	0.002
*JM068	mine drainage	Liberty Bell mine, Alaska	0.027
*JM069	mine drainage	Newsboy mine, Alaska	0.002
*JM070	mine drainage	AMS mill, Alaska	0.004
JM071	spring (hot)	Manly Spring, Alaska	0.010
*JM072	stream	Glen Gulch Creek, Alaska	0.030
*JM073	stream	Kilarney Creek, Alaska	0.007
*JM074	stream	Omega Creek, Alaska	0.004
*JM075	stream	Seattle Creek, Alaska	0.002
*JM076	stream	Rath Creek, Alaska	0.004
*JM077	stream	Upper New York Creek, Alaska	0.012
*JM078	stream	Tanana Creek, Alaska	0.002
*JM079	stream	Sullivan Creek, Alaska	0.003
*JM080	stream	New York Creek, Alaska	0.018
*JM081	mine drainage	Vergilia mine, California	0.002
JM082	spring	Nogalita Spring, southern New Mexico	0.002
JM083	well	windmill, southern New Mexico	<0.001
JM084	well	Frank Well, southern New Mexico	0.001
JM085	spring	Turkey Spring, southern New Mexico	0.003
JM086	spring	Rock Spring, southern New Mexico	0.005
JM087	spring (hot)	Geronimo Spring, southern New Mexico	0.003
JM088	well	domestic well, southern New Mexico	0.004
JM089	well	Witch well, southern New Mexico	0.004
JM090	well	artesian well, southern New Mexico	0.004

TABLE 2 (continued)

Sample no.	Sample source	Location	Concentration of gold (ppb)
JM091	well	irrigation well, southern New Mexico	<0.001
JM092	well	domestic well, southern New Mexico	0.003
JM093	well	Windmill, southern New Mexico	<0.001
JM094	well	Robinson well, southern New Mexico	0.002
JM095	stream	Bonner Canyon Creek, southern New Mexico	0.002
JM096	well	well, southern New Mexico	<0.001
JM097	spring	Aragon Spring, southern New Mexico	0.002
JM098	spring (hot)	Faywood Spring, southern New Mexico	0.001
JM099	well	windmill, southern New Mexico	0.005
JM100	stream	creek in Black Canyon, southern New Mexico	<0.001
JM101	stream	creek in Black Canyon, southern New Mexico	0.002
JM102	spring (hot)	Gila Spring, southern New Mexico	0.002
JM103	spring (hot)	San Francisco Spring, southern New Mexico	0.001
JM104	spring	spring, southern New Mexico	0.003
JM105	spring	Quarter Corner Spring, southern New Mexico	0.003
JM106	stream	Straight Creek, Utah	0.002
JM107	spring	Salt Spring, central Utah	0.003
JM108	spring	Johnny Canyon Spring, east-central Nevada	0.006
JM109	well	well in Dry Valley, Nevada	0.005
*JM110	mine drainage	La Compania mine, Chile	2.800
JM111	stream	Creek, Henry Mountains, Utah	<0.001
JM112	stream	Corral Creek, Henry Mountains, Utah	<0.001
JM113	stream	Straight Creek, Henry Mountains, Utah	0.003
JM114	stream	Straight Creek, Henry Mountains, Utah	<0.001
JM115	stream	Straight Creek, Henry Mountains, Utah	<0.001
JM116	stream	Straight Creek, Henry Mountains, Utah	<0.001
JM117	spring (hot)	Wendel Spring, Skedaddle Mountain, northern California	0.005
JM118	spring (hot)	Amedee Spring, northern California	0.006
JM119	spring (hot)	spring, northern California	<0.001
JM120	spring	Little Cottonwood Spring, northern California	0.002
JM121	spring	spring, northern California	<0.001
JM122	spring	spring, northern California	0.001
JM123	spring	spring, northern California	0.002
JM124	spring	spring, northern California	<0.001
JM125	spring	spring, northern California	<0.001
JM126	spring	spring, northern California	0.002
JM127	spring	spring, northern California	<0.001
JM128	spring	spring, northern California	<0.001
JM129	spring	spring, northern California	0.002
JM130	spring	spring, northern California	<0.001
JM131	spring	spring, northern California	<0.001
JM132	spring	spring, northern California	0.001

*Sample collected from mineralized area.

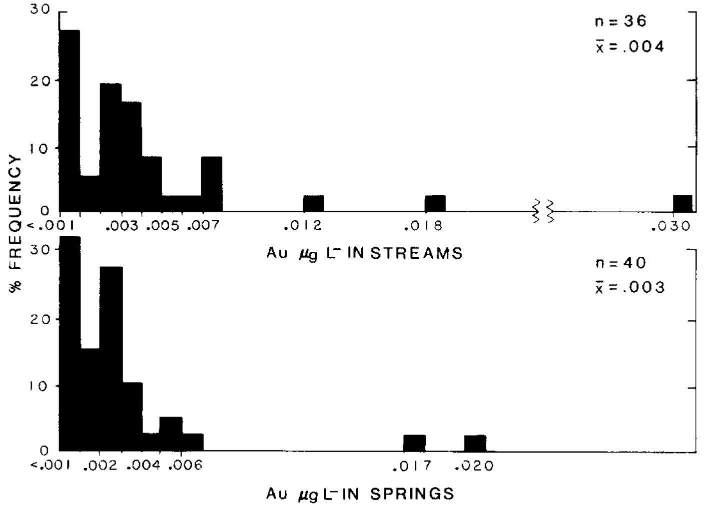

Fig. 1. Histograms for gold concentrations in stream and spring waters.

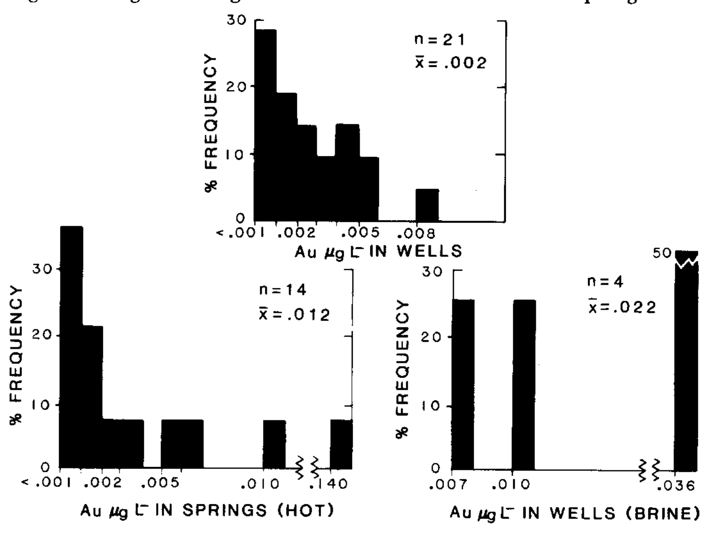

Fig. 2. Histograms for gold concentrations in well, brine well, and hot spring waters.

interference in the analytical procedures; and (2) by not filtering the sample, one is analyzing not only for ionic and colloidal gold but also for gold associated with large sediment particles.

Figure 4 shows histograms for gold concentrations in waters collected from mineralized and unmineralized areas. Mineralized areas in this report refers to those areas that are known or believe to be associated with gold. The 100 samples collected from unmineralized areas have a mean gold value of 0.002

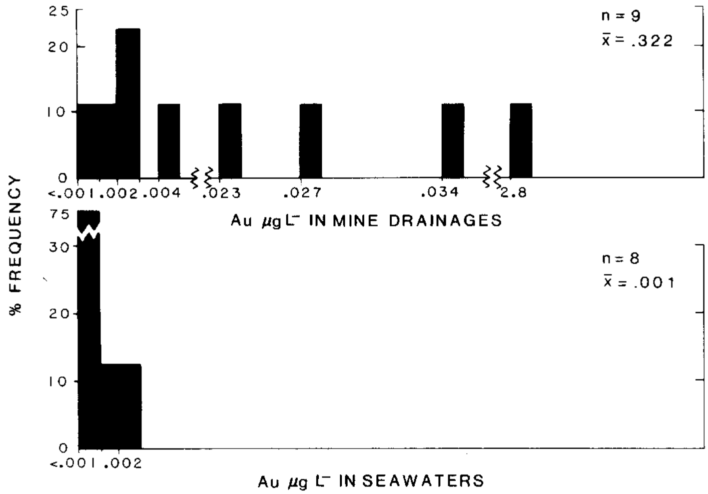

Fig. 3. Histograms for gold concentrations in sea waters amd mine drainage waters.

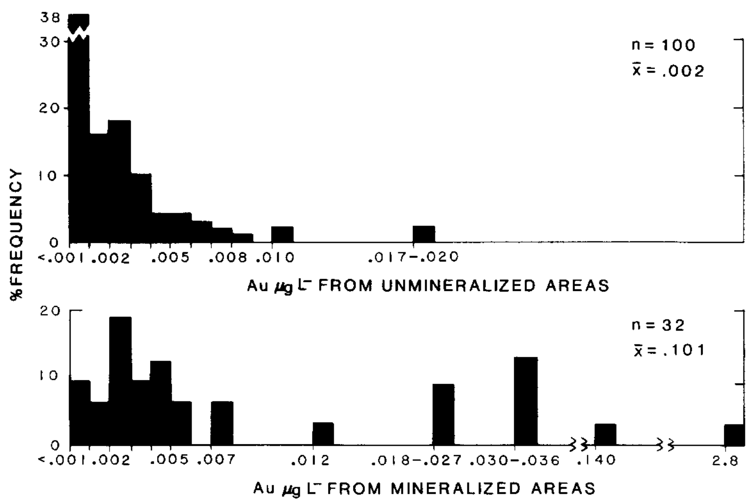

Fig. 4. Histograms for gold concentrations in waters from mineralized and unmineralized areas.

ppb. The 32 samples collected from mineralized areas have a mean gold value of 0.101 ppb.

Hamilton et al. (1983) stated that background concentrations for gold in waters from certain areas in Australia range from 0.001 and 0.003 ppb and anomalous concentrations range from 0.010 and 0.130 ppb. Goleva (1968) reports levels as high as 6 ppb for gold in water from mineralized areas in the Ural Mountains, Russia. I conclude from those reports and from the data of this study that background concentrations of gold in natural waters are probably in the range of <0.001–0.005 ppb. Anomalous concentrations of gold in natural waters from mineralized areas are probably in the range of 0.010–2.8 ppb.

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