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Gold and Silver Content of Plant *Helichrysum Arenarium*, Popularly Known as the Golden Flower, Growing in Gümüşhane, NE Turkey

A. Vural*

Gumushane University/Faculty of Engineering and Natural Sciences, Department of Geological Enginering, Gümüşhane, Turkey

Geochemical and biogeochemical methods in mineral exploration have been widely used in recent years because of the depletion of known deposits and the need to explore buried deposits. The aim of this study was to investigate the gold and silver content of *Helichrysum arenarium*, popularly known as the golden flower, for possible exploration of precious ore deposits. For this purpose, plant samples of the respective plant parts (roots, stem-leaves and flowers) collected from Demirören village of Gümüşhane in the northeastern Turkey were analysed for gold and silver by using inductively coupled plasma mass spectrometry. Gold and silver contents of the plants was assessed on the basis of different statistical approaches. The results indicate that the plant has elevated levels of gold and silver concentrations, particularly in the case of gold. As a result, it was determined that the gold content of *Helichrysum arenarium* is remarkable and the gold accumulation capacity of the plant is high in the the stem-leaves, whereas the silver accumulation capacity of the plant is high in roots.

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1. Introduction

Since the known economic ore deposits are being depleted over time, there is a need to discover new, especially buried, ore deposits. For this purpose, a number of exploration methods, such as general geochemical prospecting, water-stream sediment-soil-rock prospecting, geophysical prospecting, and exportation drilling are used to elucidate anomalous zones in the regolith above buried mineralization. Biogeochemical prospecting is also one of the exploration techniques, which can be cheaper and also effective, especially in areas with moderate topographic relief [1–2]. This prospecting technique involves the sampling and chemical analysis of plant or tree tissues to obtain information about the underlying substrate [3–4].

The basis of biogeochemical prospecting is that plants uptake nutrients and elements from soils or underlying substrate through their roots, and accumulate certain elements in their organs, such as roots, stalks and leaves. Therefore, if certain plants contain abnormally high concentrations of certain metals, they can be used as bioindicators of the substrate's anomalous geochemical attributes (e.g., the presence of mineralization) [1, 5, 6]. Although the biogeochemical approach to mineral prospecting is cost effective compared with other prospecting techniques, the major limitation of biogeochemical approach to mineral exploration is due to poor knowledge of trace element uptake and cycling by various plant species. Consequently, there is more work to be done on biogeochemistry, especially in Turkey, considering its great diversity of flora.

*e-mail: alaaddinvural@hotmail.com

2. Materials and methods

Helichrysum arenarium is a perennial plant also known as dwarf everlast or immortelle, and it is popularly referred to as "the golden flower" [7]. It grows to be, on average, 0.3 m tall. The leaves are flat, and the lower leaves are elliptical in shape while the upper leaves are linear. They are woolly on both sides. The flower heads are arranged in what can be loosely described as a cross between the umbel and panicle inflorescences. They are 3 to 4 mm wide, consisting of bright golden-yellow florets. In Turkey, *Helichrysum arenarium* is commonly found in the Northeast Black Sea Region and East Anatolian Region in high plateaus and arid rangeland, at altitudes from 250 to 3200 m.

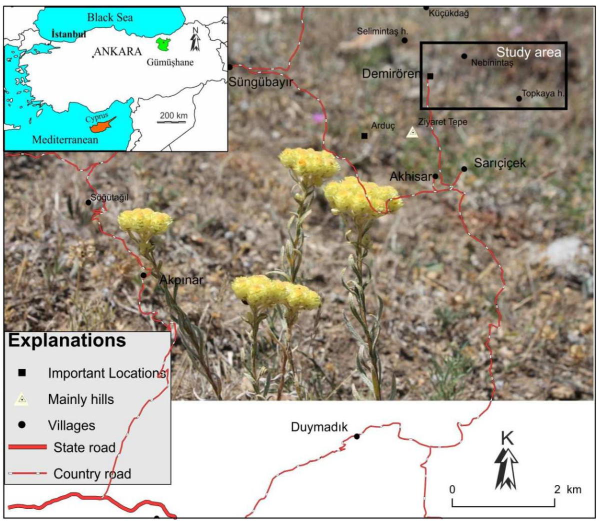

Fig. 1. Location map of the study area and *Helichrysum arenarium* from the area.

The principal objectives of this study were to determine gold and silver concentration ranges of the plant *Helichrysum arenarium*, popularly known as the golden flower, in order to: (a) study the geochemical characteristics, (b) investigate the bioindicator capacity for gold exploration, (c) evaluate the applicability of biogeochemical prospecting for mineralizations in East Black Sea region, especially in Gümüşhane and its vicinity. For this purpose, 102 plant samples of the respective plant parts (roots, stem-leaves and flowers) were collected from Demirören village of Gümüşhane in the northeastern Turkey (Fig. 1). The study area, situated in Demirören and its close vicinity, approximately 50 km east of Gümüşhane, was hydrothermally altered.

The sampled plants were individually placed in plastic bags, and immediately transferred to the Geochemistry Laboratory of Gümüşhane University, Turkey. All parts of the plant samples were cleaned thoroughly with freshwater in order to remove soil and dust particles, rinsed with ultra-pure water and then dried at room temperature for two weeks. Thereafter, air-dried samples were dried in an oven at 60 °C to a constant weight for at least a day. The samples were then powdered homogeneously and sent to ACME laboratory (Canada) to determine silver (Ag) and gold (Au) content using inductively coupled plasma mass spectrometry (ICP-MS). During the analysis process, 1.000 g of leaf samples were kept in 2 ml HNO_3 solution for 1 hour. The samples were then added to 6 ml of 2:2:2 HCl-HNO_3-H_2O_2 solution, dissolved at 95 °C for 1 h and analysed with ICP-MS (Perkin Elmer (Elan 9000), USA). The standards, STD V16 and STD CDV-1, were used during the analytical process of determining trace elements in the leaves. Thus, the accuracy and precision of the technique was assured by analysing these certified reference materials.

3. Results and discussion

All data were assessed for descriptive statistics (Table I), and a bar diagram was plotted for silver and gold concentrations of the plant parts (Fig. 2). Elemental Ag (all in ppb) was in the range of 4–47 with a median of 15 in the roots of the plant, 2 to 36 with a median of 7 in the stems of the plant and 2–13 with a median of 3 in the flowers of the plant. High Ag values were obtained in the roots. Au was in the range of 0.4–5.8 with a median of 1.50 in the roots, 0.2–34 with a median of 18 in the stems and 0.3–34 with a median of 1.9 in the flowers of the plant. High Au values were obtained in the stems.

Silver and gold concentrations found in parts of the plant were normalized (Fig. 3) by those of the soil, in which the plant grew. Soil concentrations were taken from Vural's Gümüşhane University Scientific Research Project report (2013). As seen in Fig. 3, although the concentration of silver in the plants is not significantly higher than that of the soil; the concentrations of gold, on the other hand, are more than 10 times higher in stems of the plants than in the soil samples. It is also seen that in some locations the concentration of gold in the roots and flowers of the plants is higher than the concentration of gold in the soil samples, but not by extreme margin.

TABLE I

Descriptive statistics of roots, stems and flowers of the plant for Ag and Au (Ag and Au in ppb).

	Ag	Au	Ag	Au	Ag	Au
	Root		Stem-leaves		Flower	
Mean	16.24	1.77	8.50	4.39	4.00	2.82
Standart error	1.48	0.19	1.02	1.13	0.70	0.52
Median	15.00	1.50	7.00	1.80	3.00	1.90
Mod	11.00	2.70	6.00	1.80	3.00	1.60
Standart dev.	8.64	1.08	5.94	6.59	2.80	2.97
Varianca	74.61	1.16	35.29	43.41	7.87	8.80
Kurtosis	3.66	4.66	13.88	9.92	7.13	7.55
Skewness	1.47	1.80	3.27	2.96	2.51	2.54
Minimum	4	0.4	2	0.2	2	0.3
Maximum	47	5.8	36	32.4	13	14.6
Number	34	34	34	34	16	33

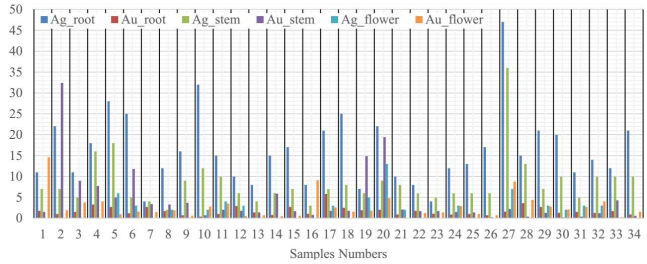

Fig. 2. Bar diagram of roots, stems and flowers of the plant *Helichrysum arenarium* (Ag and Au in ppb).

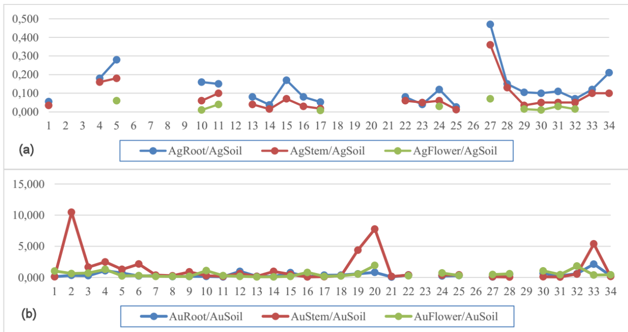

Fig. 3. Silver and gold concentrations of the parts of the plant normalized by those of the soil in which the plant grew.

The anomaly maps of the concentration of gold and silver were created and are presented in Fig. 4 for both soil and plant samples. The concentration values of gold and silver in the soil samples were shown as contour maps. On the other hand, the concentration of gold and silver in plant parts were presented as points, the size of which is proportional to the concentration values. As seen from the figure, there seems to be no close correlation between the concentration of an element in the soil and the in plant part samples. It is also evident from the figure that the concentrations of these elements in the plant part samples are higher than those of the soil samples, especially in alteration areas.

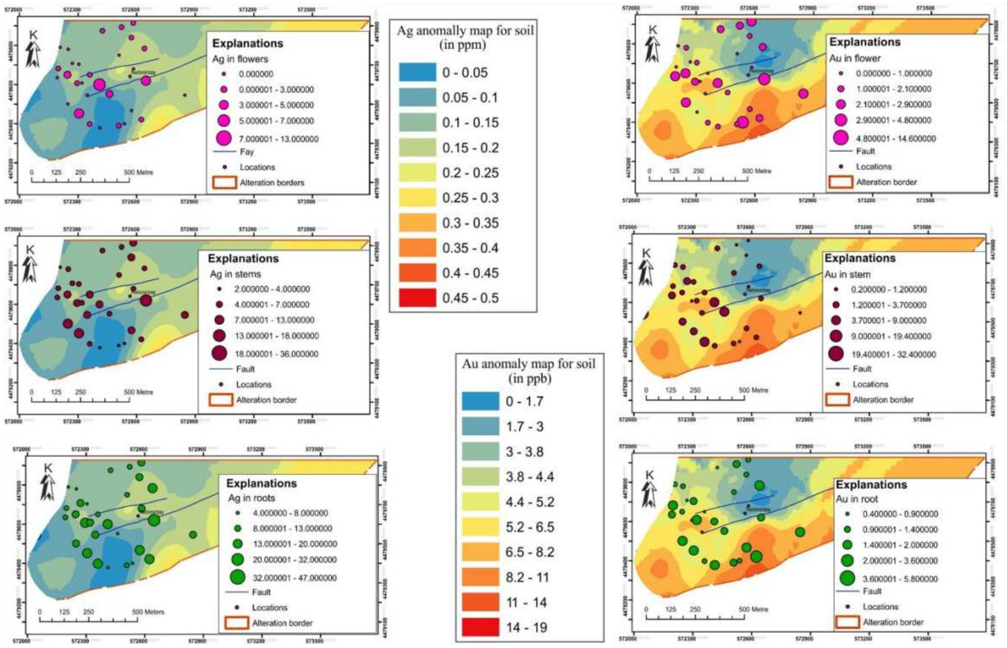

Fig. 4. Silver and gold concentrations of the parts of plants normalized by those of the soil in which the plant grew.

Plants can absorb Au in soluble form, and when Au enters the root vascular systems of plants, it can be easily transported to the top of the plant [6]. According to references in Kabata-Pendias and Pendias [8], cyanogenic plants and some deciduous trees are able to accumulate even greater than 10 ppm of Au, in terms of dry weight (DW). Although horsetail species are also known as good indicators for Au, a number of them were reported to have Au in the range of 0.1 to 0.5 ppm, measured in terms of ash weight, and only slightly higher Au concentrations were found in plant samples from mineralized areas.

Although various Au concentrations ranging from to 0.01 (FW) to 22 ppb (DW) in vegetables have been reported by some researchers, background Au concentrations are typically < 1 ppb (DW) in vegetation [8]. Smith and Carson [9] reported Ag concentrations in plants ranging from 0.03 to 0.5 ppm (DW). However, there are no data on the Au and Ag content of *Helichrysum arenarium* in the literature, and thus the current study is a novel study. When Ag and Au concentrations in different parts of the plant were compared with the data in the literature, the Ag values of the plant were not remarkable, but the Au values were noteworthy.

4. Conclusions

The results indicate that the plant has elevated levels of gold and silver concentrations, particularly in the case of gold. As a result, it was determined that the gold content of *Helichrysum arenarium* is remarkable, and the gold accumulation capacity of the plant is particularly high in the stem-leaves, whereas the silver accumulation capacity of the plant is high in the roots. These results suggest that the plant can be used for biogeochemical exploration for precious ore deposits.

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