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A new occurrence of placer gold in the Marathousa area (central Macedonia, N.Greece)

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ABSTRACT: The morphology and the chemical composition of placer gold grains in Marathousa area are studied for the first time. The auriferous sediments contain up to 4.20 ppm gold. The decrease in the Ag contents of the gold grains from the up- to the downstream is attributed to the 20 km transport. Concerning the origin of the studied placer gold, various sources can be suggested, a fact which is of great importance for future exploitation.

1 INTRODUCTION

The studied area is close to the villages Doumpia, Marathousa and N. Apollonia, 50 km east of Thessaloniki, Northern Greece, and belongs to the Mygdonia basin (Fig. 1). A big torrent, Megalo Rema and its affluent Mikro Rema, drain the basin, towards lake Volvi. Our investigations in the area started during 1986. They are carried out in the framework of a project financed from the General Secretariat of Research and Technology of Greece and the Research Commitee of the University of Thessaloniki. They deal with the chemical composition of primary and placer gold in Northern Greece and also with the chemical composition of archaeological gold samples from the Neolithic to Hellenistic era. The archaelogical investigations have concluded that the area was an important center during the antiquity and the famous Via Egnatia was passing through it. Also, remnants of older gold-washing exploitation were found in the Mikro Rema river.

2 GEOLOGICAL SETTING

Tectonically the investigated area belongs to the Serbomacedonian massif and the Circum Rhodope belt. The Serbomacedonian massif consists of two-mica gneisses, biotite gneisses, garnet bearing two-mica shists and amphibolites, which belong to the pre-Mesozoic Vertiskos group. The Circum Rhodope belt consists of the Gamila-Doubia unit (metasediments, volcano-sedimentary series and limestones), the Melissochori-Cholomon unit (metapsammites, quartzites, phyllites, recrystallized limestones, marbles and calc-shists) and the Aspri Vrisi-Chortiatis unit (metasediments, limestones, phyllites, schists and intercalations of ophiolites). A two mica and/or the biotite granite (Arnea granite) of Late Jurassic age intrudes the Vertiskos group (Kockel et al. 1977).

Miocene to Pliocene sediments and Quarternary alluvial deposits of up to 150 m in thickness, overlie the basement. The Neogene/Quarternary deposits are distiguished in the Premygdonian and the Mygdonian groups (Psilovikos & Sotiriadis 1983, Koufos et al.1995). In the investigated area, the Premygdonian group is represented mainly by the lower Gerakarou formation (red beds and intercalated sandstones and marls) and the upper Platanochori formation (sands, sandstones, conglomerates, silty sands, silt-clays, marls and marly limestones). The overlying Mygdonian group consists of coarse clastic sediments, followed by fine sediments and sandstones, gravels, sands and travertines. Gold-bearing disseminated pyrite or sulphide mineralizations in the adjacent area (Doumpia, Zagliveri and Nea Madytos locations) have been described by Mack (1964), Vavelidis (1990, 1994), Vavelidis and Tarkian (1995). Systematic investigations in the Megalo Rema and Mikro Rema rivers revealed for the first time the presence of placer gold. The present study aims at studying the morphology and chemical composition of placer gold grains.

3 ANALYTICAL METHODS

Polished thin sections of the heavy-minerals fraction and gold were studied using reflected light microscopy and a JEOL 840A scanning electron microscope at the University of Thessaloniki, Greece. Chemical analyses of the ore were carried out by ICP at ACME Analytical Laboratories, Vancouver, Canada. Electron microprobe analyses on gold grains were carried out by a Cameca Camebax microbeam electron microprobe at the University of Hamburg, Germany. An accelerating potential of 20 kV and a beam current of 15 nA were employed. The beam diameter was <1 μm and the measuring time 20 sec. Pure metals were used as standards. Corrections were applied using the Cameca computer program PAP.

4 MORPHOLOGY AND CHEMICAL COMPOSITION OF PLACER GOLD

Systematic investigation and sampling along the Megalo Rema and Mikro Rema rivers (Fig. 1) revealed the existence of placer gold. Gold is hosted within the Miocene to Pliocene sediments and Quarternary alluvial deposits of the Premygdonian and the Mygdonian groups. The highest gold contents were found mainly in the conglomerates and the alluvial gravels. The thickness of the gold-bearing depositions exceeds 50 m in some cases, mainly in the downstream part, near Nea Apollonia area. The heavy ore minerals in the auriferous sediments are magnetite, ilmenite, ilmenite/hematite, limonite and gold. Garnet, sphene, epidote, amphibole, pyroxene and apatite are the main transparent minerals of the heavy fraction of the sediments.

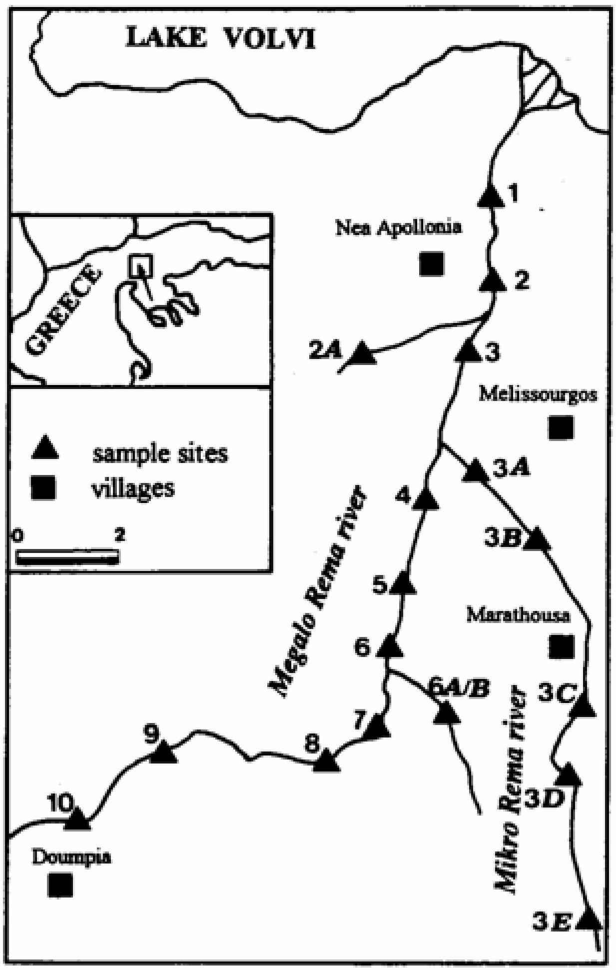

Fig. 1. Sketch map of the Megalo Rema and Mikro Rema rivers with the sampling sites.

Five representative samples of the auriferous sediments were analyzed for gold by ICP. The results showed significant amounts of gold, ranging from 0.60 to 2.30 ppm. The highest gold contents (up to 4.20 ppm) are present in the conglomerates.

The size of the placer gold grains in the investigated area ranges between 30 μm and 0.80 mm, and in some cases it reaches up to 1.30 mm. The average size of the placer gold is 0.50 mm. Gold occurs as flakes or grains, which show a significant variation in their morphology, depending on the influence of plastic deformation during gold transport. Gold flakes without or with slight deformation are elongated, massive and their shape is irregular, botryoidal or oval (Fig. 2, type I). Gold grains with high deformation are rounded and occur as bent or folded flakes (Fig. 2, type II) and in some cases they have a sandwich-like form resulted from the repeated folding. Gold grains with smooth surface or scratches and spongy appearence were also found. In some gold grains inclusions of pyrite and quartz, with sizes from 5 μm to 20 μm, were observed. Besides fragments of quartz, pyrite or limonite are usually seen in close intergrowth with gold grains (Fig. 3). Under the microscope the polished sections of placer gold revealed reflectivity and colour differences within individual grains, forming a zonal marginal rim or irregular patches (Fig. 4).

Detailed electron microprobe analyses of 101 placer gold grains from the 17 sampling sites, show significant variations mainly in their distribution of silver. The Ag contents measured on the gold grains range berween 0.85 wt % and 24.05 wt%. Table 1 shows

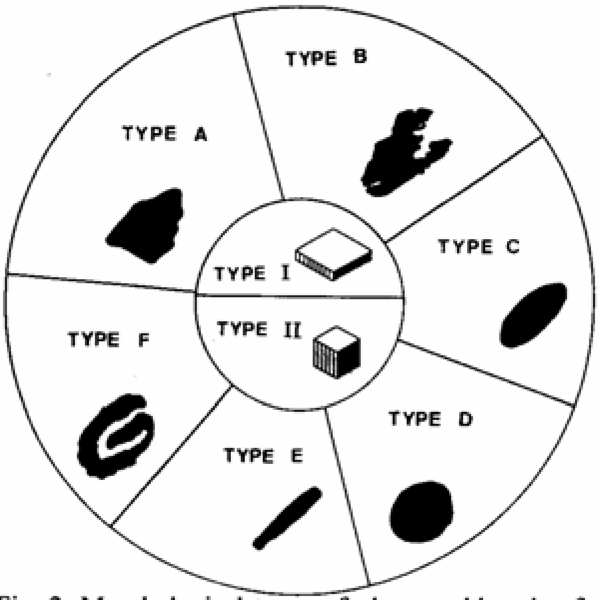

Fig. 2. Morphological types of placer gold grains from the Megalo Rema and Mikro Rema rivers, Marathousa area I. A. irregular B. botryoidal C. oval shape - II. D. rounded E. elongated F. bent or folded shape.

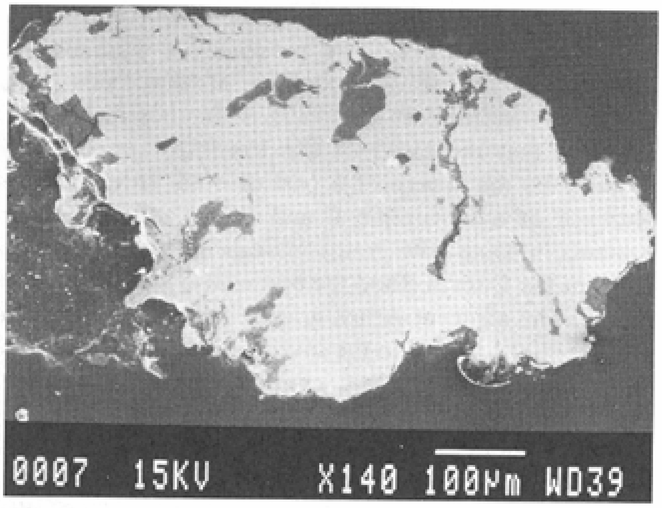

Fig. 3. Gold grain intergrown with remnants of quartz (dark). Polished section, SEM.

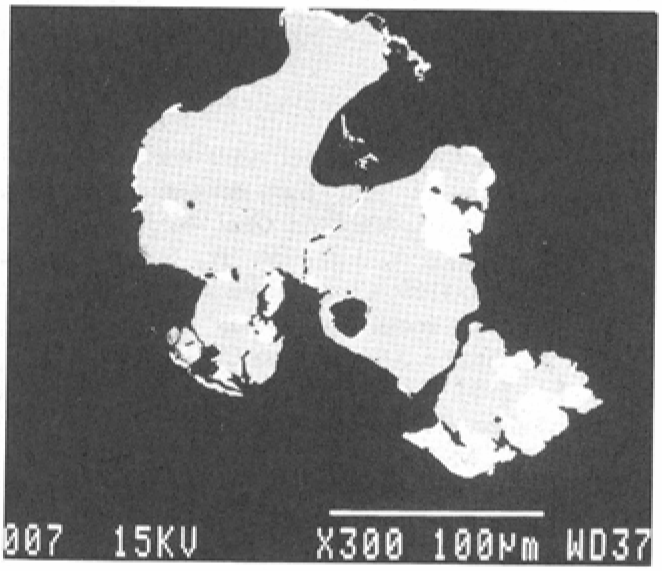

Fig. 4. Gold grain with silver poor (white) and silver rich (grey) sites. Polished section, SEM, back scattered image.

that the minimum average silver contents of the studied gold grains are 1.23 wt% (sample 1) and the maximum 14.20 wt% in the Mikro Rema river (sample 3E) and 12.75 wt% in the Megalo Rema river (sample 10). This corresponds to a decrease of 12.97 wt% and 11.52 wt% Ag from the upstream to the downstream part of Megalo Rema river (Fig. 5) and its afluent, Mikro Rema river, caused by about 20 km transport. The chemical study of gold grains revealed a characteristic zonation with different silver contents between core and rim (Fig. 5). These zoned grains exhibit an obvious enrichment tendency in gold from the core to the margins with a corresponding gold impoverishment. Table 2 shows three represantative examples of gold grains with such

Table 1. Average chemical composition and atomic % of the gold grains from the 17 sampling sites, Megalo Rema and Mikro Rema rivers, Marathousa area.

wt %	Au	Ag	Cu	Pt	Os	Ir	Tot
1.	99.14	1.23	0.08	0.02	0.04	0.05	100.56
2.	97.05	2.74	0.06	0.02	0.03	0.08	99.98
2A.	88.56	10.85	0.12	0.02	0.06	0.05	99.66
3.	94.42	5.68	0.12	0.02	0.03	0.07	100.34
3A.	89.60	10.35	0.08	0.02	0.02	0.07	100.14
3B.	87.89	12.00	0.08	0.04	0.02	0.08	100.11
3C.	88.00	12.65	0.05	0.01	0.03	0.06	100.80
3D.	86.05	14.08	0.05	0.02	0.03	0.07	100.30
3E.	86.37	14.20	0.05	0.01	0.07	0.03	100.73
4.	93.20	6.95	0.07	0.01	0.03	0.07	100.33
5.	92.98	7.25	0.06	0.01	0.01	0.05	100.36
6.	91.77	8.65	0.07	0.03	0.03	0.08	100.63
6A/B.	80.82	11.20	0.10	0.01	0.02	0.04	100.19
7.	90.30	9.77	0.06	0.02	0.02	0.05	100.22
8.	92.00	8.30	0.06	0.02	0.04	0.05	100.47
9.	89.98	10.41	0.03	0.02	0.05	0.10	100.59
10.	88.26	12.75	0.06	0.02	0.02	0.03	101.14
Avg	90.85	9.36	0.07	0.02	0.03	0.06	100.39
	Atomic %						
1	$Au_{97.44}Ag_{2.21}Cu_{0.24}Pt_{0.02}Os_{0.04}Ir_{0.05}$						
2	$Au_{94.80}Ag_{4.89}Cu_{0.18}Pt_{0.02}Os_{0.03}Ir_{0.08}$						
2A	$Au_{81.34}Ag_{18.20}Cu_{0.34}Pt_{0.02}Os_{0.06}Ir_{0.05}$						
3	$Au_{89.68}Ag_{9.85}Cu_{0.35}Pt_{0.02}Os_{0.03}Ir_{0.07}$						
3A	$Au_{82.31}Ag_{17.36}Cu_{0.23}Pt_{0.02}Os_{0.02}Ir_{0.07}$						
3B	$Au_{79.76}Ag_{19.89}Cu_{0.23}Pt_{0.04}Os_{0.02}Ir_{0.07}$						
3C	$Au_{79.03}Ag_{20.74}Cu_{0.14}Pt_{0.01}Os_{0.03}Ir_{0.06}$						
3D	$Au_{76.80}Ag_{22.95}Cu_{0.14}Pt_{0.02}Os_{0.03}Ir_{0.06}$						
3E	$Au_{76.73}Ag_{23.03}Cu_{0.14}Pt_{0.01}Os_{0.06}Ir_{0.03}$						
4	$Au_{87.74}Ag_{11.95}Cu_{0.20}Pt_{0.01}Os_{0.03}Ir_{0.07}$						
5	$Au_{87.32}Ag_{12.43}Cu_{0.17}Pt_{0.01}Os_{0.01}Ir_{0.05}$						
6	$Au_{85.03}Ag_{14.64}Cu_{0.20}Pt_{0.03}Os_{0.03}Ir_{0.08}$						
6A/B	$Au_{81.00}Ag_{18.65}Cu_{0.28}Pt_{0.01}Os_{0.02}Ir_{0.04}$						
7	$Au_{83.29}Ag_{16.45}Cu_{0.17}Pt_{0.02}Os_{0.02}Ir_{0.05}$						
8	$Au_{85.62}Ag_{14.10}Cu_{0.17}Pt_{0.02}Os_{0.04}Ir_{0.05}$						
9	$Au_{82.36}Ag_{17.40}Cu_{0.09}Pt_{0.02}Os_{0.05}Ir_{0.09}$						
10	$Au_{78.95}Ag_{20.82}Cu_{0.17}Pt_{0.02}Os_{0.02}Ir_{0.03}$						

zonation. The differences in the silver contents between the core and the rim range from 4.6 to 16.70 wt%. This natural refinement of gold can be attributed to a selective depletion of silver which took place during fluvial transport (Desborough 1970). The different composition in the same gold grain is also displayed by the above mentioned different reflectance under reflected light microscope (Fig. 5), which is visible when the differnces of the silver contents between the core and the rim is more than 4.6 wt% (Tab. 2).

Concerning the copper contents of placer gold grains, they reach up to 0.25 wt% (0.07 wt% on average). The average platinum, osmium and iridium contents are 0.02 wt%, 0.03 wt% and 0.06 wt% respectively. Iridium showed the highest contents between the PGE in placer gold, reaching up to 0.20 wt%, whereas osmium up to 0.12 wt% and platinum up

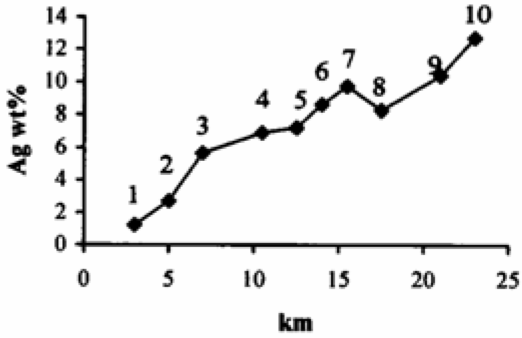

Fig. 5. Average silver contents in gold grains versus the distance of transportation.

Tab. 2. Microprobe analyses of three representative zoned gold grains from the Megalo Rema river. (1) core, (2) rim.

Sample		Cu	Au	Ag	Tot
3	1	0.12	98.30	1.65	100.07
	2	0.15	81.65	18.35	100.15
	2	0.05	81.75	18.40	100.20
	1	0.05	97.80	1.95	99.80
5	1	0.02	90.15	9.85	100.02
	2	0.03	82.87	17.25	100.25
	2	0.03	82.68	17.50	100.23
	1	0.03	89.67	10.15	99.85
9	1	0.18	89.05	11.02	100.25
	2	0.13	83.97	15.65	99.75
	2	0.15	84.30	15.60	100.05
	1	0.15	88.92	11.05	100.12

to 0.10 wt%. It should be mentioned that an Ir-rich mineral (sized of 10 μm) were found intergrown with an individual gold grain.

5 DISCUSSION-CONCLUSIONS

Nowadays placer gold deposits show an increasing interest because of their lower exploitation cost. It is therefore of great importance for the prospection of new placer gold resources to determine where the primary gold source is. Significant information for the primary gold sources can be obtained by the mineralogical composition of the heavy fraction, the mineral intergrowths and the chemical composition of the gold grains, especially of the Ag, Cu and PGE contents.

Gold grains in the investigated area can be derived from various potential sources. The adjacent Au-bearing quartz veins with sulphide mineralization (Vavelidis 1994) and the disseminated pyrite or limonite hosted in gneisses of the Zagliveri area (Mack 1964, Vavelidis 1994) are possible sources for a part of gold. The metamorphic rocks of the Vertiskos group could be another possible gold supplier for the Megalo Rema and the Mikro Rema rivers. In these metamorphic rocks, besides the gold-bearing mineralizations, the gold contents are relatively high, ranging from 0.85 to 0.95 ppm (Vavelidis 1994). The presence of disseminated native gold in the amphibolites of the Sykia area (Kassoli-Fournaraki et al. 1989) is another fact which indicates that the rocks of the Vertiskos group could possibly be the source of a part of gold. However, the presence of a PGE-mineral and the relatively high Ir contents in some gold grains indicate that the ophiolitic rocks of the Circum Rhodope belt is also a possible gold source. The adjacent Arnea granite can not be excluded as a supplier for gold in the investigated rivers, although this granite is in tectonic contact with the Vertiskos group and lacks any skarn mineralizations around it. Finally, it should be denoted that the placer gold within the alluvial sediments of the Mygdonia basin represents at least second cycle placers, resulting from the reworking of the Neogene/ Quarternary auriferous sediments of the Mygdonia basin.

All the above mentioned facts result in that the studied placer gold is originated from various sources. This is of great importance for future exploitation.

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