A new genetical ore formation model as a transition from Kuroko-type massive sulfide deposits to copper porphyries in the East Pontic metallotect, NE Turkey

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ABSTRACT: The Murgul deposit in the East Pontic metallotect is assigned to a subvolcanic formation connected with an Upper Cretaceous island arc volcanism developed temporally under subaerial conditions whereas the deposits at Madenköy and Lahanos in the western part are genetically associated with a submarine hydrothermal activity in this volcanic sequence. There is a Cu-Mo belt in the northern part of the Anatolian micro plate. The Murgul deposit can be interpreted as a transition from Kuroko-type massive sulfide deposits to copper porphyries and might be considered as a new genetical model (Murgul type).

1 INTRODUCTION

Murgul is still one of the principal copper deposits of Turkey and located in the eastern part of the East Pontic metallotect (Fig. 1) which hosts a great number of base metal deposits and represents an island arc system developed during Lias through Miocene time period (Özgür, 1985; Dieterle, 1986). The metallotect consists of a 2.000- to 3.000-m-thick volcanic sequence with relatively thin intercalations and lenses of marine sediments. The East Pontic volcanic sequence has been divided into three volcanic cycles (i.e. Maucher, 1960; Maucher et al., 1962; Akin, 1979; Özgür, 1985; Özgür & Schneider, 1988; Schneider et al., 1988; Fig. 2):

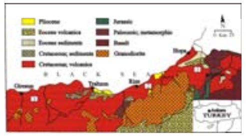

Fig. 1: Geologic setting and location map of the East Pontic metallotect. 1: Murgul, 2: Madenköy, 3: Lahanos (Özgür, 1993a).

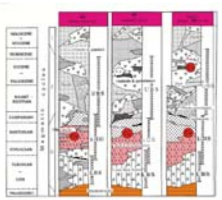

Fig. 2: Simplified lithostratigraphic column of the East Pontic metallotect. LBS: Lower Basic Series, LDS: Lower Dacitic Series, UBS: Upper Basic Series, Cu: Base metal deposits.

(i) The first cycle comprises a volcanic pile deposited between Jurassic and Upper Cretaceous and is characterized by a basal sequence of basaltic volcanic rocks which changes to felsic lava flows and thick pyroclastic rocks in the middle and top part of the cycle.

(ii) the second cycle starts with volcanic breccias, tuffs and minor intercalations of marine sediments overlain by andesitic and rhyolitic flows. The volcanic sequence is in turn overlain by limestones of uppermost Cretaceous age (Maastrichtian).

(iii) The late cycle consists of a basal sequence of marine sediments of Paleocene age which are overlain by andesitic and basaltic lava flows representing Tertiary volcanic activity.

The base metal ratios of the important deposits in the strongly altered pyroclastic rocks of Senonian age changes along the general strike of the metallotect from E (Cu>>Pb+Zn) to W (Pb-Zn >>Cu) progressively. In the western part, the sulfide ore deposits are predominantly stratiform, i. e. Madenköy (Cagatay & Boyle, 1980; Dieterle, 1986) and Lahanos (Tugal, 1969), whereas in the eastern part they are generally strata-bound (stockworks, veins, and disseminations, i.e. Murgul (Özgür, 1985). The aim of this paper is to represent volcanogenic massive sulfide deposit of Murgul generated under subaerial conditions as a new genetical ore formation model showing a transition from Kuroko- type deposits to copper porphyries in the East Pontic metallotect

2 GEOLOGIC SETTING

The copper ore deposit of Murgul occurs within the upper part of the first volcanic cycle and is associated with a 250-m-thick felsic pyroclastic rocks whose upper contact is marked by a thin layer of marine sediments and characterized by intense erosion and weathering (Fig. 3; Özgür, 1985; Schneider et al., 1988). The pyroclastic host rocks are to grade into Senonian according to paleontological observations (Buser & Cvetic, 1973) and overlain by an alternation of tuffs, sandstones and limestones and 200 to 500-m-thick barren dacitic lava flows.

The pyroclastic host rocks consist of altered breccias and tuffs. Their primarily mineral components can be observed only in few remnants. In less altered samples, the fluidal groundmass contains fragments of phenocrysts (plagioclase - An_{28-35} and quartz) and plagioclase microlites (An_{12-30}), relics of hornblende and biotite, quartz, and minor quantities of apatite, sphene, and haematite (Özgür & Schneider, 1988; Schneider et al., 1988).

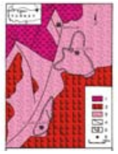

Fig. 3: Geologic sketch map of the Murgul deposit. 1: Andesitic lava flows, 2: hanging dacitic lava flows, 3: dacitic pyroclastic rocks: host rock of the orebodies, 4: main faults, 5: boundary of the open pits, 6: investigated area of Murgul (Özgür & Schneider, 1988).

3 HYDOTHERMAL ALTERATION AND MINERALIZATION

The copper deposit of Murgul is mainly mined in two open pits of Anayatak and Çakmakkaya. The mineralization is associated with a two-stage alteration of pyroclastic host rocks: (i) an initial stage of phyllic and argillic alteration, and a late stage characterized by silicification (Özgür, 1985; Özgür & Schneider, 1988; Schneider et al., 1988). The study of the rare earth element distribution in the alteration zones supports a distinction between the both alteration stages and reveals a close correlation between increasing wall-rock alteration and depletion of the rare earth elements (Schneider et al., 1988).
The first stage of hydrothermal alteration led to destruction of the primary paragenesis of the pyroclastic rocks and to the replacement of the host rock by quartz and pale green to greasy sericite. An extensive but poor mineralization of disseminated pyrites and chalcopyrite of type 1 (Fig. 4; Schneider et al., 1988) took place during the first stage. There is a relative sharp contacts between phyllic and argillic zones containing 1- to 3-m-wide transition spheres. The phyllic zone is surrounded by a pervasive argillic alteration zone in which the alteration assemblage consists of quartz, montmorillonite, dickite, illite, pyrite, and chalcopyrite.
The late stage of hydrothermal activity is characterized by silicic alteration which consists of quartz replacement of the volcanic host rocks as a cryptocrystalline jasper. The mineralized veins and veinlets cross of types 2 and 3 (Figs. 5 and 6; Schneider et al., 1988) crosscut the altered pyroclastic host rocks. The last both ore types can be interpreted to be younger phase of ore remobilization (Özgür & Schneider, 1988) which was generated by a last episode of volcanic activity. During this time period mechanical disintegration took place, opening faults and fissures for ascending ore-bearing solutions which resulted in the formation of the stockworklike mineralization (type 2). Finally, the latest open-space fillings (type 3) suggest ore mineralization closely below the terrestrial surface.
The intensively hydrothermal alteration shows a sharp contact with the upper part of the pyroclastic host rocks. Thereon, the sulfide ore mineralization discontinues in vertical profile as well. The hydrothermal alteration seems to be distributed in its association with the pyroclastic host rocks of the upper part of the first volcanic cycle and can be considered, therefore, as standard stratum field geological.
The Murgul deposit consists of (i) a widespread disseminated ore with varying Cu contents ranging from 0,2 to 0,7 percent (type 1), (ii) a stockworklike ore with average Cu contents between 1,0 and 2,5 percent (type 2), and (iii) small ore lodes with Cu contents from 5,0 to 10,0 percent (type 3).
The Ore mineral assemblage of the Murgul deposit consists of pyrite and chalcopyrite with minor contents of sphalerite, galena, fahlore, aikinite, hessite, and tetradymite (Özgür, 1985; Özgür & Schneider, 1988; Willgallis et al., 1990). For the fist time, native gold was detected in some polished sections (Fig. 7; Özgür, 1985; Özgür & Schneider, 1988).

A NEW GENETICAL ORE FORMATION MODEL

The base metal deposits of the western part of the East Pontic metallotect, i.e. Madenköy and Lahanos, are related submarine-hydrothermal activity in a volcano-sedimentary sequence under temporarily subaquatic conditions (Özgür, 1993a) and represent Kuroko-type deposits. In comparison, the copper deposit of Murgul can be assigned to a subvolcanic-hydrothermal deposit with an island arc volcanism under subaerial conditions (Fig. 8). Moreover, the presence of Cu-Mo belt in the northern part of the Anatolian micro plate (Taylor & Fryer, 1980; Taylor, 1981) can be considered as a genetical and paragenetical indications of plate tectonic position of the East Pontic island arc development accompanied by base metal deposits. Therefore, we interpret the copper deposit of Murgul as a transition type between Kuroko-type deposits and copper porphyries (Murgul type).
The following observations establish subvolcanic character of the deposit:

(i) The sparsely and only locally intercalated marine sediments in the thick volcanic sequence indicate a shallow-water depositional environment at least for the mineralized upper part of the first volcanic cycle. In Murgul, there are no stratiform mineralizations in the sedimentary lenses intercalated into the pyroclastic sequence and the adjacent stratified pyroclastic rocks of the same stratigraphical level.

Therefore, the mineralization is endogenetic in respect to the development of the volcanic pile (Schneider et al., 1988). In contrast, there are synsedimentary ore enrichments in the real submarine tuff depositions of the East Pontic metallotect (Maucher, 1960; Maucher et al., 1962).

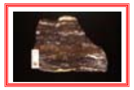

Fig. 4: Fine-grained and disseminated ore type (type 1) with intergrowths of quartz, sericite, and clay minerals, locally depicting the layered structure of the pyroclastic matter. Anayatak open pit (Özgür, 1985; Schneider et al., 1988)

Fig. 5: Stockwork ore (type 2) in strongly altered pyroclastic host rock from the Anayatak open pit (Özgür, 1985; Schneider et al., 1988).

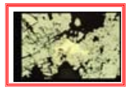

Fig. 6: Open-space filling (type 3) of a short vein from the Çakmakkaya open pit with euhedral crystals of pyrite, chalcopyrite, and quartz (Özgür, 1985; Schneider et al., 1988).

Fig. 7: Native gold (Au) in pyroclastic host rocks among the pyrite minerals. Polished section, plane polarized light, oil immersion. 40 X 12,5.

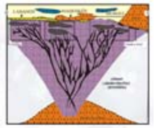

Fig. 8: Schematic presentation of the ore deposits of Murgul, Madenköy, and Lahanos in the East Pontic metallotect (Özgür et al., 1991; Özgür, 1993a).

ii) The pyroclastic sequence in the upper part of the first volcanic cycle was altered and mineralized during a late stage of the volcanic activity by ascending hydrothermal fluids.

(iii) The formation of the orebodies of Anayatak and Cakmakkaya must have been completed before a short time interval of intense subaerial erosion and weathering took place (Özgür, 1985). The short interval is represented by a thin strongly kaolinized layer of reworked pyroclastics and sediments like a regional marker bed (Özgür, 1985; Dieterle, 1986) which is taken as evidence for a temporal terrestrial formation conditions.

(iv) The mineralized and strongly altered host rocks are overlain by a series of relatively low-grade altered and barren volcanic rocks. The mineralization does not traverse the marker bed. This emphasizes that the deposits were formed prior the erosional interval and the later eruption of the hanging wall volcanic rocks.

(v) The altered and mineralized host rocks show structures similar to the "ore-related breccias" described by Sillitoe (1985). They suggest a local subsurface brecciation which might have been generated by repeated volcanic activities reheating the system, because there is evidence for several nearly contemporaneous eruption centers at a distance of a few hundred meters. The Murgul deposit shows some similarities to porphyry ore deposits described by Lowell & Guilbert (1970), but there are some remarkable differences (Fig. 9; Schneider et al., 1988), i.e. (1) the high-grade ore is mainly concentrated in the center, (2) there is no potassic alteration zone observable, and (3) the mineralization must have taken place relatively close to the surface. The $\delta^{34}S$ values of sulfides in Murgul and Lahanos range from 2,33 to 4,83 per mil (Fig. 10) and are comparable with the values of the Kuroko-type deposits (Ohmoto et al., 1983).

From Jurassic to Lower Cretaceous, an island arc volcanism was generated which can be proven by geochemical discrimination of spilites from Murgul and its environs (Özgür, 1985). In Senonian, the output and deposition of volcanic materials increased, that the sea water was displaced from Murgul and its environs temporarily and deposited shallow water sediments at the border of island arc locally. In the time interval, in which the first volcanic cycle was developed, the formation of the copper deposit of Murgul took place. In a sphere of approximately 1 to two km^2, the deposited pyroclastic rocks and small thick sediments were altered by hydrothermal fluids in various phases. The base metal deposits are generated in connection with two-stage alteration processes. Thereby, repeated tectonic events led to break of silicified host rocks increasingly and opened further fissures for an increasingly mineralization thereby.

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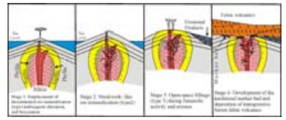

Fig. 9: Formation of the copper deposit of Murgul in a schematic representation (Schneider et al., 1988).

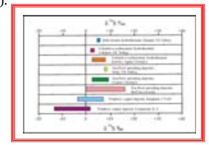

Fig. 10: Sulfur isotope data for the deposits Murgul and Lahanos and a comparison with the other ore deposits

Finally, the copper deposit of Murgul resulted from at least three periods of increasing concentration of the ore materials (Fig. 6; Schneider et al., 1988). After the deposition of the thick dacitic to rhyolitic pyroclastic sequence, subsequent volcanic activity caused the disintegration of the pile at isolated small centers, thus producing optimal permeability. During this stage hydrothermal fluids spread upward forming the first phase of disseminated pyrite and chalcopyrite mineralization (type 1). The continuation of hydrothermal activity led to an additional concentration of ore matter into two younger generations of vein mineralization (stockworklike ore: type 2; open-space fillings: type 3).
Fluid inclusion measurements in quartz crystals associated mainly with ore types 2 and 3 show formation temperatures up to 285 °C and salinity of 5 percent NaCl equivalent which can be considered as an epithermal character (Özgür, 1985).
In Murgul, the enrichment of fluorine and the depletion of manganese and titanium in the pyroclastic host rocks are suitable for the exploration of blind ore deposits in the East Pontic metallotect as pathfinder elements in connection with hydrothermal alteration (Özgür, 1993b).

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