GOLD AND SILVER IN ANATOLIA

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ABSTRACT

According to the latest archaeological records, gold mining in Anatolia goes back to 3,000 B.C. and silver mining as early as 4,000 B.C. Troians and Lydians were the leading gold-producing civilizations. Lydians are known to have used golden coins for the first time.

Gold has been recovered from quartz veins or auriferous sands in rivers in ancient times. As a result of almost depletion of high-grade vein deposits and placers exploration efforts have recently been focused on low-grade and high-tonnage epithermal precious metal deposits and porphyry gold deposits which had been formerly regarded as uneconomic. This resulted in discoveries of numerous deposits in global scale. Also, some epithermal and porphyry gold deposits were discovered in Turkey.

The territory of Turkey can be divided into four main tectonic zones from north to south, i.e., Pontides, Anatolides, Taurides and Border Folds. The present geologic picture of Turkey has been shaped in neotectonic period beginning from Middle Miocene when Arabia and Anatolia collided along the Bitlis Suture. This collision resulted in uplift, basin formation, and development of major faults in Anatolia. During the Late Miocene, the Anatolian block began to move westwards. As a result, four main neotectonic provinces are defined in Turkey; east Anatolian contractional province, north Turkish province, central Anatolian ova province, and west Anatolian extensional province. Of these, the west Anatolian province is dominated by extensional tectonics much like the Basin and Range of the western US where numerous gold – silver deposits occur.

The gold – silver deposits of Turkey can be classified as epithermal – type deposits, porphyry – type deposits, skarn deposits, mesothermal deposits, VMS deposits, and placer deposits. Of these types, epithermal deposits appear to have premier importance for precious metal in terms of abundance because Tertiary volcanics closely associated with them occur widespread especially in western Turkey dominated by extensional tectonics. The only gold deposit that is currently being
mined is Ovacık deposit near Bergama. The Gümüşköy deposit is the only silver – producing epithermal deposit in Turkey. Turkey has also high potential with respect to porphyry – type gold (± Cu–Mo) deposits as exemplified by recent discoveries in different parts of Turkey (Çöpler, Kışladağ etc.)

Current total gold content of the mining deposits and other deposits having mineable reserves is about 338 tons. Silver content that can be recovered from these deposits is 5740 tons. Gold content is 84 tons in potential deposits and silver content is 80 tons. Additionally, 95 tons of metal gold and 2515 tons of metal silver have been determined from the deposits in which gold and silver can be recovered as by – products.

Turkey annually imports 200 tons of gold on an average, amounting to about $ 2.5 billion. An essential amount of this figure is consumed in jewelry – manufacturing sector.

With its too complicated geological structure and lithological diversity, Turkey has favorable conditions for precious metal deposition. The western Turkey characterized by manifestations of extensional tectonics has great potentiality particularly with respect to epithermal – type deposits. Intrusive rocks which can be related to porphyry – type deposits commonly occur in various parts of Turkey. The eastern Pontides characterized by island – arc tectonic setting has suitable conditions for the formation of VMS deposits in which gold and silver can be as by-products in near future, new discoveries could be made by further exploration efforts.
INTRODUCTION

Latest archaeological records document that gold mining in Anatolia goes back to 3,000 B.C. Silver mining dates back as early as 4,000 B.C. Anatolia is the cradle of civilizations as well as mining. The leading gold-producing civilizations are the Troians and Lydians. Strabon, the famous geographer, reports that gold from the treasures of Priamos, the Trojan king, was mined from Astrya mines 25 km away from the city of Troy. Herodot, the famous historian, reports that gold making the treasures of Kroisos, the Lydian king was mined from auriferous sands in Pactolos river (Sart) that has orginated in Tmolos Mountain (Bozdag). The Lydians are known to have used golden joins for the first time. Ancient mining records belonging to the Roman period have been found near Ovacik-Bergama, Kucukdere-Havran and Sogut-Bilecik during exploration works. In the second half of the 19th century, foreign companies mined gold from Kartaldag/Madendag (Kirazli-Canakkale), Arapdag (Karsiyaka-İzmir), and Kiseçikkoç (Hatay). Prior to the World War I, the Russians mined gold near Darphane (Kagizman-Kars).

Gold was recovered from quartz veins or auriferous sands in rivers in ancient times. Because, exploration efforts have recently been focused on low grade-high tonnage epithermal deposits and porphyry deposits which had been formerly regarded as uneconomic, almost depletion of high-grade vein deposits and placers. This resulted in discoveries of numerous deposits in global scale. Beginning from early 1980s, Turkey has experienced a kind of ‘gold rush’ similar to that in California in 19th century. Particularly, MTA and other domestic and foreign companies have explored for epithermal precious metal deposits in Western Anatolia having favorable conditions for precious metal deposition. As a result of these exploration efforts, a great number of gold-silver mineral occurrences have been discovered. During the last decade, some porphyry gold-copper deposits were also discovered in different part of Turkey.
The Anatolian peninsula constitutes a part of the Alpine-Himalayan-Indonesian mountain range in the Eastern Mediterranean realm. Owing to the pronounced NS shortening of the belt relative to the neighboring areas, geology of Turkey exhibits a complicated picture. Simplistically, the territory of Turkey can be divided into four main tectonic zones, i.e., Pontides, Anatolides, Taurides, and Border folds.

The Pontide Belt, Northern Anatolia between the Izmir-Ankara-Erzincan Suture Zone and Black Sea comprises three major tectonic units juxtaposed in Late Mesozoic. The Strandja (Istranca) Massif in the northwestern border of Turkey contains gneissic rocks intruded by Upper Paleozoic (244 my) granitoids. Around Istanbul, a famous Paleozoic sequence called the Paleozoic of Istanbul crops out. This zone is characterized by a well-developed, unmetamorphosed and slightly deformed Paleozoic sequence (sedimentary rocks). To the south and east of the Istanbul Zone lies the Sakarya Zone. The Neo-Tethyan Intra-Pontide Suture Zone separates the northwestern Anatolia from the rest of the Pontides within the Sakarya Zone. The Permian-Triassic aged Karakaya Complex is the most important element of the Sakarya Zone. It consists of deformed basic volcanics, greywackes with limestone olistoliths (Permain and Carboniferous) and metaophiolite wedges.

Anatolides comprise rock sequences virtually identical to those of the Taurides but a widespread greenschist facies metamorphism appears as the distinctive characteristic. Anatolides also include some HP (high pressure) / LT (low temperature) zones as well as HT / LP metamorphic rocks forming the well-known western and central Anatolian massifs.

Taurides extend from the Aegean Sea along the Mediterranean coast to the eastern Anatolia. They characteristically comprise several nappes piled up together onto some sparse autochthons and para-autochthons. The Tauric nappes in general consist of carbonate (Mesozoic) and clastic (Paleozoic) rocks of a typical passive continental margin (except eastern part). In the eastern Anatolia to the north of Border Folds, imbrications of nappes and crustal shortening form the eastern Anatolian Accretionary Complex (EAAC).
The Border Folds region constitutes the Arabian platform in the territory of Turkey. The South East Anatolian Tertiary Thrust Zone (or Bitlis Suture) delimits the region in the north and separates it from the EAAC. The thrust zone represents the collision line between the main Gondwana Mass and the continental slivers once separated from it. Due to the still continuing collision, this region is characterized by broad folds. The rock sequences of the region represent the passive margin of the Arabian continental block. Several anticlines characterize the region. Some of the buried anticlines constitute the major petroleum reservoirs of Turkey.

The neotectonic period for Anatolia begins in the Middle Miocene when Arabia and Anatolia collided along the Bitlis Suture. The ongoing crustal compression due to the collision along the Neo-Tethyan sutures resulted in uplift, basin formation, and development of major faults in Anatolia. During the Late Miocene, the Anatolian block began to move westwards. As a result, four main neotectonic provinces are defined in Turkey; east Anatolian contractional province, north Turkish province, central Anatolian ova province and west Anatolian extensional province. Of these, the west Anatolian province is dominated by extensional tectonics much like the Basin and Range of the western US and has an estimated extension of between 30% and 50%. The most striking manifestation of this extension is the 10 to 11 major east-west trending grabens and intervening horsts. Both western Anatolia and the Basin and Range are seismically active areas. Western Anatolia is also an area of high average geothermic gradient. One reflection of this is that both areas contain numerous hot springs (Turkey has more than 600 hot springs). Many of these hot springs that discharge subeconomic concentrations of gold with mercury and antimony as its pathfinders are modern analogs of fossil hydrothermal systems.
CLASSIFICATION OF GOLD-SILVER DEPOSITS

The gold-silver deposits of Turkey can be classified on the basis of some criteria including temperature of formation, host rock characteristics, ore mineralogy, other elements associated with gold, and geodynamic setting of ore deposition, etc. The following classification is descriptive.

1. Epithermal-Type Deposits: They form at shallow depths or near surfaces at low temperatures (<300 °C). They are mostly associated with Tertiary rhyolitic to dacitic or even andesitic volcanics. They also occur in metamorphic, ultramafic, and sedimentary rocks. They occur within crushed and multi-phase breccia zones or as quartz veins, stockwork veinlets, and/or disseminations in these rocks. Accompanying alteration assemblages include silicification, argillization, advanced argillic alteration, sericitization, and propylitization. The most important volcanic-hosted deposits are Bergama-Ovacik, Havran-Kucukdere, Izmir-Arapdagı, Canakkale-Kartaldag and Madendag, and Kutahya-Gumuskoy deposits. The Ovacik deposit is currently being mined. The Gumuskoy deposit is the only silver-producing deposit. Similar deposits are found along listwaenite zones in ultrabasic rocks. The Sivrihisar-Kaymaz and İnegol-Suluklugol deposits belong to this type of mineralization. Sedimentary-hosted deposits can be exemplified by Balikesir-Kepsut-Beykoy and Bilecik-Sogut deposits.

2. Porphyry-Type Cu-Mo-Au and Au Deposits: Turkey has a high potential with respect to porphyry-type Cu-Mo-Au and Au deposits. These deposits occur in relation to subvolcanic intrusions ranging in composition from quartz diorite to granodiorite. Particularly, the porphyry-type deposits that have been recently discovered are the biggest deposits with their metal gold contents. The new discoveries include Erzincan-Ilic-Copler and Usak-Esme-Kisladag deposits.

3. Skarn-Type Deposits: They commonly occur in association with porphyry systems. However, they may form as separate mineral occurrences. These deposits have small potential
with respect to precious metals. Skarn type deposits can be exemplified by Balikesir-Edremit-Altinoluk, Elazig-Keinan-Zeytindag, and Kutahya-Domanic-Saricayirayyla deposits.

4. **Mesothermal Deposits:** They usually occur as veins, veinlets, or replacements. This type of mineral deposits occur very widespread although they usually have small reserves. Gold and silver usually accompany lead and zinc with copper in these veins. Their silver contents may be pretty high. The Giresun-Sebinkarahisar-Asarcik, and Gumushane-Sobran deposits are good examples for this type of deposits. Besides, a great number of gold-bearing arsenopyrite veins commonly occur in metamorphics throughout the Menderes Massif. These veins have high Au contents and are regarded as refractory ore. İzmir-Odemis-Kure occurrence is included in this class.

5. **Volcanogenic Massive Sulfide Deposits:** Gold and silver are produced as by-products from this type of deposits. Massive sulfide deposits are divided into 2 subclasses. The first is the Kuroko-type deposits which occur widespread in the Eastern Black Sea region. They are associated with the later stages of island-arc formation and more felsic volcanics. All deposits exhibit a close time-space relationship to fragmental submarine volcanics of dacitic to rhyolitic composition. This type can be exemplified by Artvin-Murgul-Anayatak, Artvin-Murgul-Akarsen, Artvin-Cerattepe and Rize-Cayeli-Madenkoy deposits. Second type is the Cyprus-type massive sulfide deposits. They are associated with spreading ocean or back-arc spreading ridges and with basic volcanics usually ophiolites. The most important examples are Kastamonu-Kure, Diyarbakir-Ergani-Anayatak, and Siirt-Madenkoy deposits.

6. **Placer Deposits:** River and beach placers as well as karstic ores are included in this category. Salihli-Sart and Hatay-Akillicay gold occurrences are known as alluvial placers whereas Kirklareli-Igneada-Mertgolu deposit occur as beach placer. Of these deposits, historically mined Sart deposit is currently being mined.

On the other hand, Nigde-Ulukisla-Bolkardag gold occurrence is found in karsts.
GOLD-SILVER POTENTIAL OF TURKEY

Total gold content of the operating mines and other deposits having mineable reserves calculated by feasibility studies is about 338 tons. The silver content that can be recovered from the same deposits is 5740 tons. Gold content is 84 tons in potential deposits and silver content 80 tons. Besides, 95 tons of metal gold and 2515 tons of metal silver have been determined from the deposits in which gold and silver can be recovered as by-products. These figures can be undoubtedly increased by further studies.

Disregarding the small-scale production from the Sart placer, the only gold-producing operation is the Bergama-Ovacik mine. A total of 23.65 tons of dore bullion was produced from this mine between the years of 2001 and 2003 and exported. The value of this production is about $120 million. On the other hand, the average silver production from the Kutahya-Gumuskoy deposit is about 85 tons, annually. This product is domestically consumed in jewelry manufacturing sector. Furthermore, a small amount of silver is produced as by-product from VMS and vein-type deposits. In recent years, Turkey annually imports 200 tons of gold (213 tons in 2003) on an average, amounting to about $2.5 billion. An essential amount of this figure is consumed in jewelry manufacturing sector. In 2002, about 85 tons of gold (could be as high as 130-150 tons by touristic and unrecorded sales) was exported as jewelry, amounting to $591 million.

CONCLUSIONS

With its too complicated geological structure and lithological diversity, Turkey has favorable conditions for precious metal formation. Tertiary calc-alkaline volcanics of dacitic and andesitic compositions occupy very extensive areas. These terranes provide suitable conditions for epithermal precious metal deposition. Particularly, the province of western Anatolia that is dominated by extensional tectonics, geologically shows similarities to the Basin and Range of the western US where numerous gold-silver deposits occur. The manifestation of this extension is many major east-west trending grabens and intervening horsts with a much greater number of smaller NE-striking grabens and half grabens.
Many hot springs are distributed along the margins of these structures. In precipitates and sinters deposited by these hot springs, subeconomical concentrations of Sb, Hg and Au were determined. Besides, in various parts of the western Anatolia, a great number of big and little antimony and mercury deposits are known to occur most of which have recently been exploited. They occur along tectonic lines, particularly in silicified zones within different lithologies. Sb, Hg, and As are very useful pathfinders in the search for epithermal precious metal deposits. Particularly, these metals are invariably concentrated on top of the gold-enriched zones. Regarding all these similarities, foreign companies initially concentrated their exploration efforts in this region. It seems possible that new discoveries could be made as a result of exploration works conducted by foreign companies and domestic governmental organizations (chiefly MTA) in various parts of the region at the present.

İslan-darc setting of the Eastern Black Sea region with its products is favorable particularly for the formation of VMS deposits and also epithermal- and porphyry-type deposits. Additionally, listwaenite zones developed within ultramafic rocks along orogenic belts offer a new target for gold exploration. New discoveries could be made by sufficient exploration efforts.

ACKNOWLEDGMENTS

The writers deeply wish to thank Hayrullah YILDIZ, Serkan OZKUMUS, Nihat YILDIRIM, Deniz TRİNGA and Ömer ALİŞIK their colleagues of M.T.A for preparing this paper in windows format, and drawing some figures in Coral Draw program. Thanks are also extended to Turan ALPAN, for providing some relevant photographs.
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