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Uranyl phosphates and associated minerals in the Koprubasi (Manisa) uranium deposit, Turkey

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ABSTRACT

The Koprubasi uranium deposit is the largest known uranium deposits in Turkey. Uranium mineralization is hosted in Neogene fluvial sediments that consist of predominantly sandstone and conglomerate interlayered with siltstone, claystone and mudstone. Sediments were primarily derived from metamorphic rocks adjacent to the basins of deposition, with some volcanic contribution in the form of tuffs. The sandstones and conglomerates are the most widespread sediments within the study area and host the majority of the U ore.

X-ray diffraction (XRD) and scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDX) analysis were used to identify the ore and associated minerals. The uranium ore minerals of the host sedimentary rocks are torbernite, meta-torbernite and meta-autunite. These coexist with jarosite, various clays (chlorite/kaolinite, illite, and smectite), and Fe- and Mn-(hydr) oxides with minor titanium oxide. Additionally, quartz, feldspars and a minor amount of mica (muscovite and biotite) are the main primary minerals in the sedimentary rocks.

The uranyl phosphates coat the surfaces of pebbles and some mineral grains, fill cracks, and are disseminated within the pores of the host sedimentary rocks. Uranyl phosphates are commonly associated with Fe-(hydr) oxides and clays, although some were observed in millimeter- or centimeter wide gaps within Koprubasi sediments. Oxides of manganese are also locally abundant and associated with uranyl phosphates.

The uranyl phosphates in the sediments of the Koprubasi area most likely formed when oxidizing groundwater moved through the host rock. The common association of uranyl phosphates with Fe-(hydr) oxides and clays suggests that the precipitation of uranyl phosphate minerals is mainly due to adsorption of the uranyl and phosphate to the surface of Fe-(hydr) oxides and clays.

1. Introduction

Koprubasi is located 120 km northeast of Manisa in western Turkey (Fig. 1). It has a typical Mediterranean climate with hot and dry summers, and mild and rainy winters. Uranium exploration in the Koprubasi area commenced in 1957 under the General Directorate of Mineral Research and Exploration of Turkey (MTA), which led to discovery of the Koprubasi uranium deposit in 1961 (Manisa) as a result of aerial and ground surveys.

Since the discovery of the Koprubasi uranium deposit, limited studies have been conducted to evaluate the geology, mineralogy, origin, and reserves of uranium (Maden Tetkik Arama, 1976; Yılmaz, 1982). Although the presence of some uranyl minerals is suggested by Maden Tetkik Arama (1976), there has been no characterization of the uranium and associated minerals and their relationships. Also, the coexistence of uranium minerals with Fe-and Mn-(hydr) oxides, clays and titanium oxides has not been previously recognized in the Koprubasi uranium deposit.

The aim of our study is to characterize the mineralogy of the Koprubasi (Manisa) uranium deposit and to examine the effect of Fe-(hydr) oxides and clays on the precipitation of uranyl phosphates. To our knowledge, this study is the first investigation reporting uranium phosphate minerals associated with Fe-(hydr) oxides (like goethite) and clays in this deposit.

2. Geological setting

Koprubasi is a district within the Manisa Province in the Aegean region of Turkey. The lithological units exposed at Koprubasi

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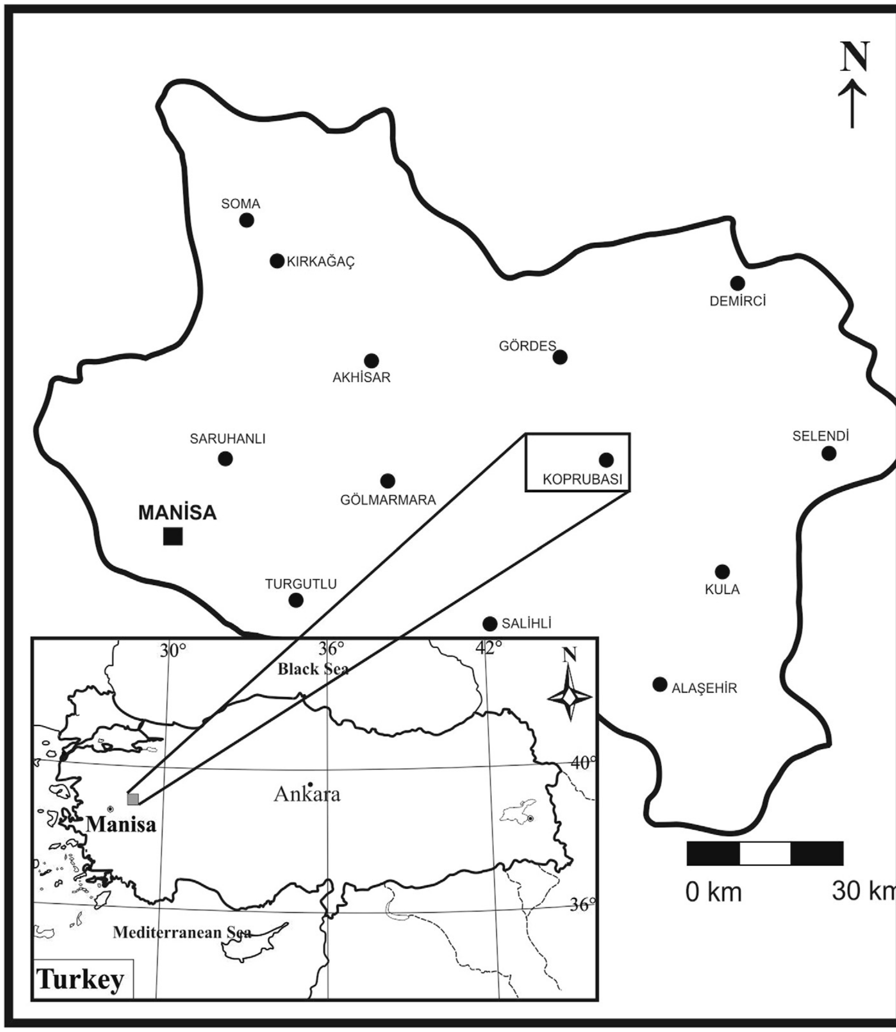

Fig. 1. Location map of the study area.

(Manisa) and nearby consist of metamorphic and sedimentary rocks. The basement metamorphic rocks are mainly banded and biotite gneisses belonging to Menderes Massif. The banded gneiss contains pegmatite dykes and quartz veins. The metamorphic rocks are overlain unconformably by Neogene sedimentary rocks consisting of, from bottom to top, fluvial and lacustrine sedimentary rocks. Neogene fluvial sedimentary rocks consist predominantly of sandstone and conglomerate interlayered with siltstone, claystone and mudstone. They are also interbedded with acidic tuffs and silicified stratum in some areas. Neogene fluvial sedimentary rocks are overlain by lacustrine sedimentary rocks that cover a small portion of the southern part of the study area that is well exposed at Tulluce. These combine mudstone, marl, siltstone and limestones, and the contact between lacustrine and fluvial sedimentary rocks is gradational (Maden Tetkik Arama, 1976; Yılmaz, 1982).

3. Samples and analytical techniques

Uranium mineralization occurs in various localities around the Koprubasi area (Maden Tetkik Arama, 1976). Therefore, radiometric measurements with a geiger counter was done while travelling by foot, principally around the Koprubasi area. The strongest radioactivities were detected at the Kasar, Ecinlitas, Topalli, Cetinbas, Ugurlu and Kayran areas. Hence, this study is focused on these areas (Fig. 2).

All samples were collected from outcrops. A portion of each sample was crushed and pulverized for subsequent chemical analyses, and a piece of each sample was retained for detailed mineralogical and petrologic studies. The textures of some sediment samples were examined in polished thin sections and in polished epoxy mounts. The mineralogy of sediment samples was determined by powder X-ray diffraction (XRD) using a Rigaku D/Max-2200 Ultima^{+}/PC diffractometer (at the Turkish Petroleum Corporation in Turkey) and a Bruker Davinci diffractometer (at the University of Notre Dame in the USA). Diffraction data were collected from randomly oriented powders. The powder specimen was packed into the cavity of the glass sample holder and then its surface was smoothed with another glass slide. The scans were conducted from 2 to 70° at 0.02°2θ step size and 1 s per step data collection time using Cu $K\alpha$ X-radiation. Additionally, where weak reflections were observed using the previously stated scan rate, additional scans were collected at 10 s per step to increase the signal to noise ratio.

A JEOL-JSM 6060 (at Dokuz Eylul University in Turkey) and EVO 50 LEO SEM and FEI-MAGELLAN 400 FESEM (at University of Notre Dame in the USA) scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectrometer (EDX) were used to characterize uranium and associated mineral morphologies. Samples for SEM-EDX analysis were prepared by adhering sediment samples with freshly broken surfaces onto an aluminum stub with double-sided carbon tape, with each sample also coated with