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Composite soil-geochemical halos delineating carbonate-hosted zinc–lead–barium mineralization in the Irankuh district, Isfahan, west-central Iran

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ABSTRACT

The Irankuh district in west-central Iran hosts several largely unexposed Lower Cretaceous carbonate-hosted Zn–Pb deposits whose host rocks are overlain by soil cover. This paper documents a detailed soil-geochemical exploration program, comprising 804 residual soil samples that were treated with a microwave acid digestion and analyzed by ICP-MS for a multi-element package. The soils overlying the Zn–Pb–Ba veins and mineralized zones have geochemical contrast and element enrichments that are more than two to twenty-one times greater than the non-mineralized background soil values. The most diagnostic elements are Zn, Pb, Ag, Ba, Hg and Sb which show multi-point anomalies across the entire mineralized zone with concentration ranges of 282–10,000 ppm Zn, 73–10,000 ppm Pb, 2.2–71.9 ppm Ag, 1500–3400 ppm Ba, 0.89–36 ppm Hg and 11–164 ppm Sb, respectively. The newly proposed composite geochemical halos defined by Ag*Cd/Pb*Zn, Ag*As/Pb*Zn, Ca*Mg/Pb*Zn, Sb*As/Pb*Zn, Hg*Sb/Pb*Zn, Sb*Ba/Pb*Zn, Ba*Ca/Pb*Zn and Ag*As* Sb/Pb*Zn*Bi correlate well with the anomalous patterns of the individual elements. The anomalies are coincident with the main faults and fractures, in particular Gushfil and Rumarmar faults of the area. On the basis of the low contents of Cu and Fe and the variodiagram of log (Pb + Zn) versus Pb/Pb + Zn, the composition of the samples suggests epigenetic stratabound Zn–Pb–Ba mineralization of the Mississippi-Valley-Type (MVT). The mode of occurrences of the anomalies is likely controlled by structural replacement in sphalerite, galena, carbonates and barite or adsorption by iron–manganese oxides and clay minerals. Follow-up sampling of gossans in highly faulted-fractured zones may indicate more concealed Zn–Pb mineralization.

1. Introduction

Although soil geochemical surveys have been successfully used in exploration for a variety of mineral deposits, including porphyry copper and volcanogenic massive sulfide deposits (Fletcher et al., 1986, pp. 129–179; Levinson, 1980, pp. 11–12; Salminen, 2011), less attention has been given to the detailed geochemical soil surveys employing composite geochemical halos associated with carbonate-hosted Zn–Pb mineralization. Because these deposits are simple in their mineralogy, chemistry and are relatively free of potential pathfinder elements, their geochemical exploration signatures are characterized by dispersion of Pb and Zn alone (Brabec, 1983). Of the two metals, Zn was found to give a greater homogeneity and more strongly contrasting anomalous patterns in soils and lake sediments (Rose et al., 1979, pp. 580). As a result of the low mobility of Pb and/or a low Pb to Zn ratio in the source rocks, the Pb anomalies are often poorly expressed (Rose et al., 1979, pp. 560). On the other hand, elements, such as Ni, Cu, Cr, Mo, and Hg, are similar to Zn in their tendency toward enrichment in the organic-rich shale relative to other sedimentary rocks (Brabec, 1983; Vine and Tourtelot, 1970). Historically, applicable models used for detection of Zn–Pb carbonate-hosted deposits have been based on the understanding of the geochemical environments (Hutchinson, 1996; Leach et al., 2001, 2010a; Rajabi et al., 2013; Sadeghi, 2003; Sangster, 1990; Sawkins, 1984).

Descriptions of detailed soil-geochemical surveys are rare in Iran. More than 600 carbonate-hosted Zn and Pb deposits and occurrences are known in the Zn–Pb metallogenic zone of Iran (Ghorbani et al., 2000). The majority of these deposits are hosted by Paleozoic–Early Mesozoic and especially Cretaceous carbonates (Fig. 1). The abundance of favorable host rocks suggests a great potential for Zn–Pb mineralization in Central Iran and in particular, in the Sanandaj–Sirjan zone.

The first study of the regional metallogenic aspects of the carbonate-hosted Zn and Pb mineralization in this zone, known as the Malayer–Isfahan Zn–Pb metallogenic belt, was presented by Momenzadeh (1976). The first composite soil-geochemical halos at Irankuh district were done by Hosseini Dinani et al. (2013). This study describes a detailed evaluation of soil-geochemical halos as a possible exploration guide for Zn–Pb mineralization at Irankuh district. The main objectives of this investigation are as follows: (1) to determine background values, geochemical contrasts, and geogenic enrichment factors of the multi-element data, (2) to recognize the most anomalous patterns of the

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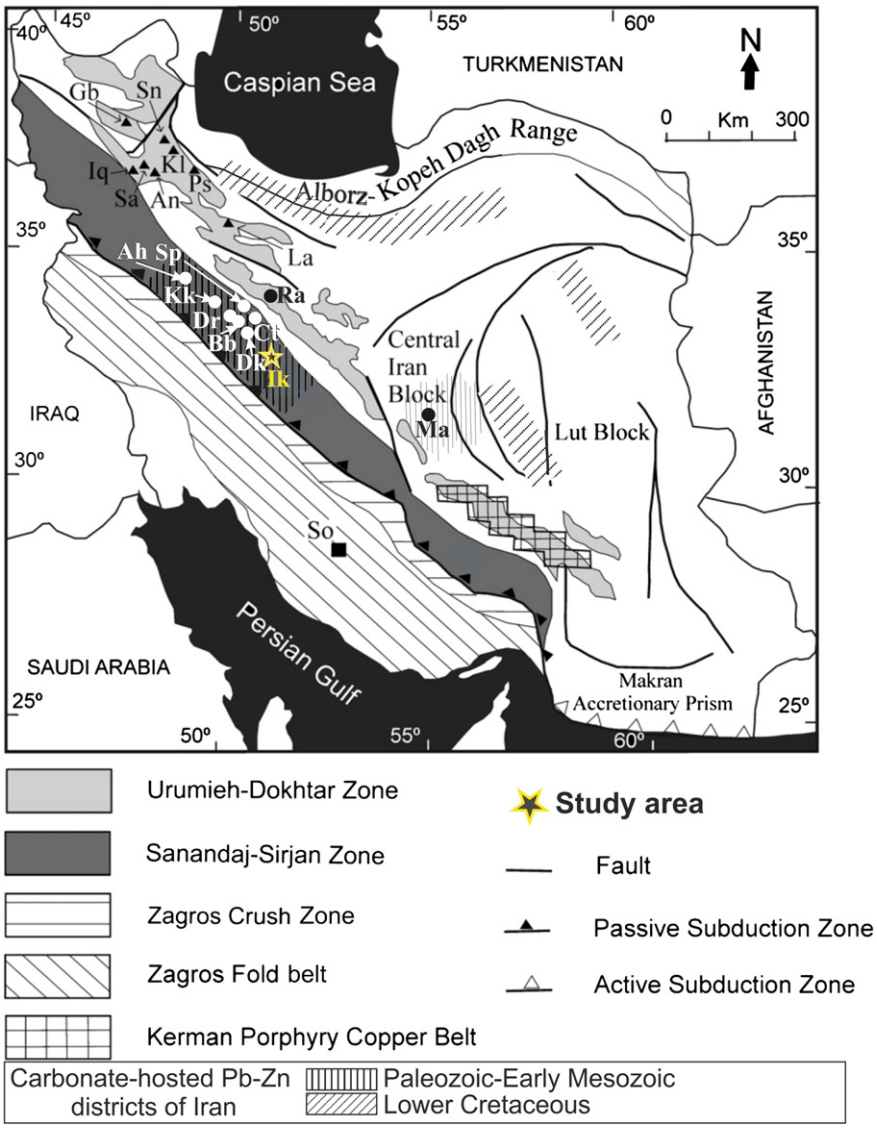

Fig. 1. Geostructural map of Iran showing the locations of the study area and associated Zn–Pb deposits, Sanandaj–Sirjan zone. Ah = Ahangaran (exhalative; Momenzadeh, 1976 and Zamanian, 1993), Kk = Koh Kolangeh (exhalative; Momenzadeh, 1976), Tp = Tappeh Sorkh (epigenetic; Ghazban et al., 1994), Kd = Kolahdarvazeh (epigenetic; Ghazban et al., 1994), Dk = Doshkharat (MVT; Ghorbani, 2007), Dr = Darenoghreh (MVT; Ghorbani, 2007), Bb = Babasheykh (epigenetic; Ghorbani, 2007), Ct = Chahtalkh (epigenetic; Ghorbani, 2007), Sp = Salehpeighambar (epigenetic; Ghorbani, 2007), An = Angouran (massive sulfide; Ghorbani, 2007; sedex, Ebrahimi et al., 2010), Sa = Saryaghol (MVT?vein?; Mirnejad et al., 2011), Ps = Pasar (vein; Mirnejad et al., 2011), Iq = Iqalesi (vein; Mirnejad et al., 2011), La = Lak (vein; Mirnejad et al., 2011), Sn = Senjedeh (vein; Mirnejad et al., 2011), Kl = Khalf (vein; Mirnejad et al., 2011), Gb = Ghebchagh (vein; Mirnejad et al., 2011), So = Kohe Sormeh (MVT; Liaghat et al., 2000), Ma = Mehdi abad (MVT; Meshkani et al., 2011), Ra = Ravanj (MVT; Modaberi and Rastad, 1998).
Modified after Aghanabati (1986), Mirnejad et al. (2011), and Stöcklin (1968).

elements, by presenting the elemental geochemical maps, (3) to assess the potential of supra-ore halos as the composite geochemical maps, and suggest promising targets for further exploration and (4) to present possible genetic models of mineralization.

2. Geographical and geological settings

The Zn–Pb–Ba mineralization of the Irankuh district is located about 20 km south-southwest of the city of Isfahan between longitudes 51° 31′ 46″ and 51° 45′ 30″ and latitudes 32° 37′ 22″ and 32° 28′ 53″ (Fig. 1) The district lies within the Sanandaj–Sirjan zone (Fig. 1). The mineralized Zn–Pb zones of the Irankuh district occur in both the northern and southern flanks of Irankuh mountain, and the most important of them are Gushfil, Tappeh Sorkh, Gardaneh, Kolahdarvazeh, Gode Zendan and Khaneh Gorgy (Ghazban et al., 1994; Rastad, 1981; Teimouri Asl, 2010; Zahedi, 1976, Fig. 2). The Zn–Pb–Ba mineralization is hosted in the Lower Cretaceous Isfahan–Malayer metallogenic belt, which hosts numerous carbonate-hosted Pb and Zn deposits. The first major deformation in the Zagros geosyncline took place in Late Cretaceous time (Kashfi, 1976) due to convergence of the Arabian and Iranian plates. Tectonic disturbance increases from the northeast to the southwest, with the highest intensity in the Irankuh–Aligoodarz fracture zone (Momenzadeh, 1976). Longitudinal faults and fractures in the Irankuh district are parallel to the main Zagros thrust faults.

3. Geology of Irankuh district

3.1. Stratigraphy

As shown in Fig. 2a, the oldest rocks in the area are Jurassic shale and sandstone, which are exposed in the northwestern part of the Irankuh district. These rocks are unconformably overlain by Lower Cretaceous shallow marine carbonates. The base of the sequence consists of a conglomerate, 5 m thick, which is covered by dolomite, limestone